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Ricard, Lykke Margot

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Lykke Margot Ricard
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Innovation and Technology Management

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Preface

This thesis is submitted to DTU Management Engineering, Technical University of Denmark in partial fulfillment of the requirements for acquiring the Doctor of Philosophy in Management Engineering degree (PhD). The work has been supervised by professor Per Dannemand Andersen, and co-supervised by senior scientist Maj Munch Andersen and senior researcher Birgitte Rasmussen. The thesis consists of a recapitulation of the research study including four research papers prepared during the period from August 2009 to January 2013. The papers included have been updated to the most recent version available from the respective journal review processes.

Lykke Margot Ricard, Kgs. Lyngby, Denmark, January 2013

CONTENTS

Acknowledgements

The thesis' journey has had its own roadmap, from the curiosity of exploring a phenomena and the stubborn determination to finish the PhD, I have encountered many great experiences, from interviewing technology experts, CEOs, and policy makers to actually presenting my research at international conferences at Stanford University in USA, Strasburg University in France, European Commission's Joint Research Centre in Seville, Spain and University of Queensland in Australia. I have met many great colleagues in all these places and received valuable feedback, for which I am thankful. The work of editors and two anonymous reviewers on the research paper (Chapter 2) accepted for publication in *International Journal of Science* and *Public Policy* and the research paper (Chapter 5) accepted with revisions by the journal *Technological Forecasting and Social Change* have been insightful learning experiences with educational feedback.

My thanks to Dr. Rob Phaal for showing me the ropes in roadmapping at Cambridge University and exchanging emails that have been very motivating, as roadmapping is academically still a niche; therefore, it has also been important for me to explore more of the context of roadmapping, of the institutional setting that evolved around certain problems and strategic directions.

Thanks to my colleagues at the department of Management Engineering, and to Kristian Borch, for being my teaching partner in scenario and roadmapping, a collaboration that which successfully ended with a publication. Thanks to my officemates Anne Nygaard Tanner and Mette Sanne Hansen, with whom the bumps along the road were the objects for many good laughs. Thanks to my former master thesis student Julie Serritslev for excellent collaboration and also for making it be about solving problems.

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Finally, I want to thank my family for reminding me that I have a life outside academia, with high responsibility and lots of love. My husband and especially our two sons for being so patient and proud of me that they want to become engineering researchers, too – all those long hours at work must mean that I am having fun. I love their simple way of reasoning.

Abbreviations

CCS	Carbon Capture and Storage
DC	Dynamic capabilities
DG Energy	Directorate General in Energy, European Commission
EFP	European Foresight Platform
ETP	European Technology Platform
EC	European Commission
EU	European Union
EWEA	European Wind Energy Association
GA	General assembling
IS	Innovation Systems or Systems of Innovation
IPCC	International Governmental Panel of Climate Change
IEA	International Energy Agency
NIS	National Systems of Innovation
RD&D	Research, developments, and demonstration
SDD	Strategic Deployment Document
SETIS	Strategic Energy Technology Information System
SET-Plan	Strategic Energy Technology-Plan
SRA	Strategic Research Agenda
TIS	Technological Information System
TSIS	Technology Specific Innovation Systems
TPWind	Technology Platform Wind
ZEP	Zero Emission Platform

Prelude

Science and technology has throughout history changed our everyday life. New technologies have crossed boarder of what was thought to be possible and man's beliefs and conception of the world have changed over time. History of science has taught us that scientific and technological revolution lead by new discoveries is possible. Scientific communities have from time to time rejected old theories and replaced them with new, when in fact the old way of looking would be considered incompatible with the new (Kuhn 1947:1970). Predicting the future has been based on limited information, however one thing that seems to evidently true, be that man's expectations has always been a part of the future.

Reference

Kuhn T. S., (1947: 1970). The Structure of Scientific Revolutions. Chicago, Chicago University Press.

1. Chapter one: Introduction

1.1 Theory and positioning

A great challenge in long-term strategic planning is dealing with a high level of uncertainty. The longer the time frame becomes, the greater the uncertainties. Not until the socio-economic shift in the 1970s, from a steadily growing economy to an oil crisis, did this become manifested in strategic planning. The limitations of economic forecasting and Cartesian modeling and planning tools in industry became obvious, as these traditional tools now failed in planning the future. Great shifts in the world economy and new technologies were not within the range of 'normal' predictions, but created a path towards more complicated and analytical approaches in strategic planning (Loveridge, 2001; Linstone, 2002; Cummings and Daellenbach, 2009).

One tool in such approaches is the roadmap, which was first used by Motorola in the late 1970s in its technology management practice. Today, it is widely used and has been extended within the last decade to general strategy application. Visually, a roadmap consists of a timeframe and vertical layers of information that are possible to align. It seeks to answer three important questions: Where do we want to go? Where are we now? How do we get there? Thus, a roadmap process essentially seeks to translate projections of future development into applied actions for present day decision making (Barker and Smith, 1995). An important scholar of strategic roadmapping calls it a flexible approach that can be "fitted to processes bringing together commercial and technical groups, creating alignments, thus creating a common language and forward view" (Phaal and Muller, 2009; Farrukh et al.; 2009; Goenaga-Larrañaga and Phaal, 2010). This view of roadmapping is close to recent views on foresight in relation to strategy, as an intermediating tool for bringing together stakeholders with focus on long-term technological developments or path creations.

To the question of what foresight is, the European Foresight Platform, which is a foresight practice community supported by the European Commission's Joint Research Centre, says: *"Foresight is a systematic, participatory, future-intelligence-gathering and medium-to-long-term vision-building process aimed at enabling present-day decisions and mobilizing joint actions."*

(http://www.foresight-platform.eu/community/foresightguide/what-is-foresight/, accessed 25 September, 2011).

Within this definition, foresight is compatible with roadmapping as a foresight method. This position was recently supported by scholars of roadmapping (Beeton et al., 2008) and foresight methodology (Popper, 2008), more specifically positioning roadmapping as a foresight vehicle.

1.1.1 The evolution of foresight rationales

Internationally, foresight has been used in national science, technology and innovation policies since the late 1980s (Loveridge, 1994; Grupp and Linstone, 1999; Cagnin and Keenan, 2008). The approach draws on and relates to many academic disciplines such as: corporate strategy, innovation systems or evolutionary economics, new public management, governance of science, and science sociology. Concerns and processes for dealing strategically with the futures of science, technology and business development have been around for several decades. Strategic foresight methods were typically developed in the US between the 1940s and 1970s – for example, by the RAND Corporation. The key literature and textbooks were typically written in the 1960s to 1980s and reflect US experiences from defense and aerospace and a linear model of innovation – consequently, an expert point of view.

Foresight involves participatory processes, and in contrast to forecasting and strategic planning traditions, it avoids prediction and is not performed by an expert or consultant group. The methods are important components of foresight activities, but they go beyond making a plan. In order for activities to be defined as foresight, they must involve a wide pool of expertise and stakeholders or create networks for coordination and knowledge sharing (Miles, 2010). The greatest difference between forecast and foresight is therefore the participatory element, which is often synonymous with foresight. The evolution of foresight rationales is moving towards increased focus on learning and the engagement of stakeholders to gather intelligence, towards not being only considered as a result-oriented and rational analytical tool.

Since its emergence in the late 1980s, foresight has been used within technology policy as a policy instrument that draws on technology experts and a strong focus on R&D

priority-setting (Lundvall and Borras, 2006). Using the web of science's social citation index from 1968 to December 2012, searches were made that were limited to the two international journals, *Futures and Technological Forecasting* and *Social Change*, which both date back to around 1968 and are representative for the evolution in (technological) forecasting and foresight.

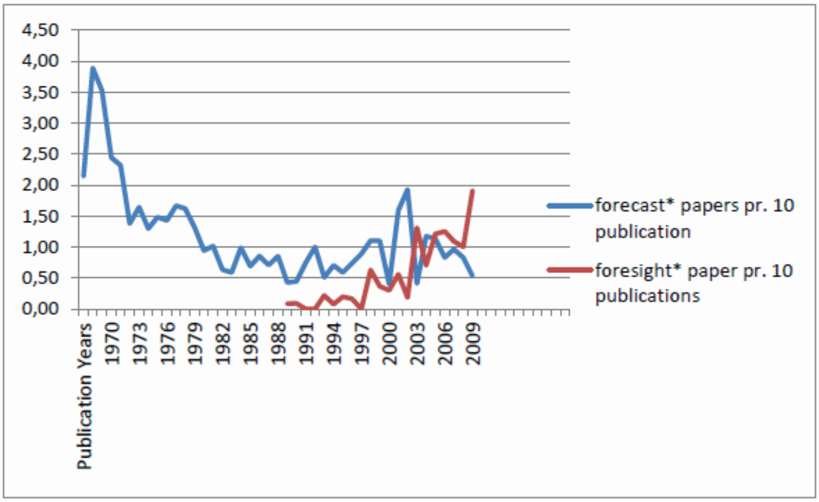
Searches were set by the following definitions:

Table 1.1.1 Search codes using web of science (December 2011)

Annual knowledge production	Total number of publications in the two journals pr. year
Forecasting, a topic search defined as	Forecast* NOT foresight* pr. year
Foresight, a topic search defined as	Foresight* pr. year

The graphs are calculated as number of foresight* papers by the total number of publications in the two journals, and number of Forecast* NOT foresight* papers by the total number of publications in the two journals per year from 1968 until 2011.

Figure 1.1.1. The term 'foresight' versus 'forecasting' in scientific knowledge production



The graph shows the trend in foresight and thus the trend in participatory processes. The trend shows high activity within foresight technology. Recently, more dedicated international journals have also appeared, and conferences dedicated to foresight take place on a regular basis. There are indications that foresight is about to emerge as an international scientific discipline, transcending such disciplines as corporate strategy, innovation systems or evolutionary economics, governance of science, and perhaps even ideas from science sociology.

Cariola and Rolfo (2004) in their paper on evolution in the foresight rationales in Europe, elaborate on an evolution in foresight rationales, and they are later supported by several innovation policy scholars (Cuhls and Georghiou, 2004; Miles, 2010; Cagnin and Keenan, 2008; Johnston, 2008; Georghiou and Harper, 2011). This literature supports five generations of foresight rationales that have emerged since the 1980s and have developed along policy perspectives:

First generation rests in the domain of economic planning.

Second generation is seen from the perspective of market failure: that many firms operate within a short horizon and intervention needs to take a long-term view while giving higher priority to research and development.

Third generation lies in the rationale linked to the system-failure perspective: that insufficient bridging exists between institutions, and that *foresight provides an arena in which the necessary network connections can be made*. The market perspective is then enhanced by inclusion of social actors. For example, user perspectives and methods are expanded to draw on knowledge of social trends and alternative institutional arrangements, such as networks.

Fourth generation foresight is distributed in the sense that various organizations carry out foresight exercises in relation to their own needs, but coordinated with related activities.

Fifth generation foresight can play a more distributed role, using a mix of foresight methods and thereby also broader inclusion of stakeholders, using e.g. expert panels and interviews with users of technology.

Clearly, the evolution in foresight rationales does not stand alone. Developments in important thematic perspectives that influence foresight rationales are essential for understanding the design and reasons behind the foresight process. The new generation of foresight practice still draws on experts to some extent, but draws to a much greater degree on relevant stakeholders and the public at large. Conventional technocratic forecasting practice does not seem to work when the focus is on the entire value chain in the overall innovative performance of the economy. This focus not only includes technocratic experts, but also business communities.

In Cariolo and Rolfo's article, "Evolution in the rationales of foresight in Europe" (2004), they highlight that the rationales of foresight in EU policy processes are more focused on involving stakeholders from business communities and the public at large. They also provide evidence that recent EU foresight activities are understood as an instrument of innovation policy, positioned within the idea of innovation systems. The following definition taken from their work is evidence that the idea of innovation systems is incorporated into EU policy, and thus wired together with the understanding of foresight as an innovation policy tool (seen in the context of the Lisbon strategy from 2001) (Borras, 2009, European Commission, 2010). Foresight is thus defined as:

> *"... an important tool in the development and management of future-oriented innovation systems, based within a wider context of future-oriented coordination activities in a society. It could be defined as a purposefully organized process bringing together expectations of diverse actors about possible development paths to formulate strategic views about the future that take into account broad social and economic developments".*

The definition was formulated by the STRATAETAN Expert Group on Foresight of the European Union DG Research, and clearly builds on foresight activities that serve as an instrument for directing innovation systems. It is acknowledged in recent foresight literature that the theoretical rationale for foresight exercises is in accordance with the system of innovation perspective and mainly an innovation policy tool (Georghiou and Harper, 2011). Therefore, developments in theoretical perspectives related to policy are essential for understanding the design and reasons behind the foresight process.

The foresight literature points to the experience that successful foresight processes must have clearly defined rationales and objectives, and lists different rationales or objectives of strategy processes. The following cluster of rationales of foresight is derived from this literature:

Table 1.1.2 Innovation policy rationales for using foresight*

Rationale 1:	Directing or prioritizing governmental investments in science, technology and innovation
Rationale 2:	Building new networks and linkages around a common vision
Rationale 3:	Extending the breadth of knowledge and visions in relation to the future
Rationale 4:	Bringing new actors into the strategic debate
Rationale 5:	Improving policy-making and strategy formulation in areas where science and innovation play a significant role

*Source: Table based on literature from Georghiou and Keenan (2006) and (Georghiou et al., 2008) (p.18) in the Handbook of Technology Foresight.

As explained in this literature, these rationales of practice collectively form a picture of foresight as a tool to extend *"…the knowledge base and the depth of analysis available to decision-makers, and at the same time through its participative element create new action networks"* (Georghiou et al., 2008, p. 20).

Deducing from this theoretical discussion, we can conclude that rationality plays a large role in understanding the reasons behind the design of foresight activities. One thing that these foresight rationales seem to have in common is the importance of stakeholders, which naturally makes sense, simply because the results and learning of such processes is either limited or broadened by the boundaries of the participating stakeholders.

1.1.2 Problem: Gap between theory and practice

In the following, I define roadmapping as a process that explores the possible future development tracks in strategy and innovation, and also the outcome of such a process, a goal-oriented roadmap, closely followed by an action plan. This definition is based on the discussion in chapter 5, where the roadmapping literature is explored to define its characteristics. Conceptually, the roadmap serves as both a strategy and communication tool to visualize the route to follow in order to reach the desired outcome of a technological development. Essentially, the roadmapping process seeks to answer three simple questions: Where do we want to go? Where are we now? How do we get to where we want to go from here?

Epistemologically, the roadmapping process assumes that we know where we want to go. This is not always the case, but it is perhaps taken for granted in current literature. One of my favorite tales is *Alice in Wonderland*, which contains a dialogue that touches on this paradox: When Alice asks the cat which road to take, the cat replies that it greatly depends on where she wants to go. Alice answers that she doesn't much care as long as she is sure of getting somewhere. Then, the cat says: Oh, you're sure to do that, if only you walk long enough. A research gap seems to exist between foresight's theory and practice and its weak theoretical foundation with regard to both its ontological and epistemological position.

Recent foresight literature focuses on participatory processes, thus moving to a broader inclusion of actors, from elite scientists towards stakeholders. This reflects an emerging practice that strongly relates to inter-subjectivity in constructivism as suggested by (Fuller and Loogma, 2009). This means that the question of to what social good the knowledge is produced is highly relevant for its legitimacy; but indeed, it also indicates interest in what seems to be at stake and the powers of the stakeholders, which affect the outcome of what in retrospect may be seen to be the most fitting hypothesis of future technological (evolutionary) trajectories. Foresight is not only emerging; it is also changing its domain, drawing on many academic disciplines, such as innovation policy (governance of science), innovation system, strategic planning and strategizing.

(Georghiou and Harper, 2011) emphasize that rationales of foresight in EU policy have changed since the 1980s: from a tool for assessing R&D priorities in the 1980s (Irvine and Martin, 1984) towards being both participatory and systemic at the same time (Cariola and Rolfo, 2004). This explains the shift in focus from the conventional technocratic, technology-driven forecasting practice towards emphasis on the important elements of stakeholder participation and networking as in Martin and Johnston (1999) "Technology foresight for wiring up the innovation system". This review discussion seems to point out that strategic foresight's function is to prepare for the future: not only to identify promising technologies, but to engage key stakeholders in turning common visions into action plans. Foresight literature is rich in processes and methods (Popper, 2008), e.g. horizon and scanning, scenarios, and roadmaps as systematic approaches to future strategy-making. Thus, arguing that foresight is more a variety of methods than actual theory. However, such new foresight rationales long for theoretical foundations to improve the value of long-term perspectives and participatory strategy processes handling various perspectives. A study of such practices may provide us with new forms of organizations, and provide new knowledge of how they organize in shaping technological trajectories around important societal challenges.

1.2 Initial studies and research objects

What is roadmapping? And what are the challenges? This introduction examines the foresight literature to show that this literature welcomes roadmapping as a foresight tool for long-term strategic planning, and that roadmap literature accepts this invitation, even though the most common roadmap literature takes its point of departure in technology management at the firm level. The roadmap framework is unique, however, compared to other foresight tools. Essentially, it introduces foresight tools to identify trends and drivers, but these are to be aligned with technological development along a long-term timeline, thus opening up e.g. for an identification of innovation gaps between today and the desired future (the vision). Thus, it captures the important point taken from Loasby (2001) that time matters to knowledge.

1.2.1 Sector level research

Why unfold the European Technology Platform's (ETP) roadmapping processes, one should ask. From the J.R. Commons (1950) perspective of institutions as creating purposeful design, institutions constitute a phenomenon of accumulated knowledge, of what has worked and what has not (Vanberg, 1997). Sometimes, when these institutions create undesirable consequences, we create new solutions, new institutions (Vanberg, 2011). This is basically the perspective for arguing why the ETPs need to be unfolded, and that the context of the roadmapping process may provide a better understanding of the theoretical underpinnings needed when focusing on sector-level research agendas.

Instead of comprehensive results from a single foresight case study, which is common in foresight literature, sector-level research is based on a theoretical discussion reflecting transformation and evolution in foresight rationales positioned within an EU shift in policy perspective, from science and technology policy towards an innovation policy perspective (Lundvall and Borras, 2006).

In chapters 2 and 3, it can be said that the research objects are embedded in the empirical files of new European innovation policy tools, from which the sector-level strategies and the foresight processes of the ETPs emerge.

The European Union's governance system operates through intergovernmental decisions negotiated by the member states, and consists of supranational organizations. Some of the most important are the following: The Parliament is the legislative body to which members are elected every four years by EU citizens. The Council of Ministers is a bicameral legislative body and consists of executive members from the member states. The European Council has no legislative power, but under the Lisbon Treaty is in charge of and defines the strategic direction and priorities of the EU. The EU Commission consists of the civil services, but this is a powerful civil service that draws up treaties, laws and policies with the right to impose its decision on EU member states. Clearly, the cohesion policy of the EU is based on negotiation processes across many levels.

The ETPs are industry-driven platforms, which within well-defined strategic areas of technologies that bring together key stakeholders, and through highly concerted research agendas, formulate a common vision and structure for technological trajectories.

The ETPs play a central role in developing strategies and research programs. The EU Commission supports the ETPs, as they are perceived to be bottom-up methods for creating long-term visions; however, it is emphasized that the platforms are not initiatives taken by the European Commission, but by the sector-level stakeholders themselves. All platforms are industry-driven. Some are supported by a Secretariat funded by the European Commission under the FP7 budget. New platforms occur all the time: In 2004, the number of existing and planned Technology Platforms was 24 (European Commission, 2004), and when FP7 was launched in March 2007, there were 31 technology platforms. From a simple count of the existing ETPs displayed on the Technology Platform website, the number is presently 36 platforms. In the European Strategic Energy Technology Plan (the SET-plan), highest priority is given to six sector-proposed initiatives within the most promising energy technologies with the aim to achieve climate and energy goals. These initiatives are in wind energy, solar energy, bio-energy, carbon capture and storage (CCS), and electricity grids and nuclear fission.

The latest evaluation report of the ETPs (IDEA Consult, 2008), which is based on surveys, finds that the ETPs were performing well in R&D prioritizing and coordination. One explanation of this could be that the strategic research agendas are implemented in the EU Framework programs, and therefore become visible effects. The Seventh Framework Program (FP7) on technology research and development, which runs from 2007 to 2013, is divided into four programs: cooperation, ideas, people and capacities, where cooperative research is the bulk in the program. Accordingly, the ETPs are mentioned in the objectives as already having an effect:

> *"The ETPs have contributed to the definition of the themes of the Cooperation programme, in particular in research areas of special industrial relevance. The implementation of the SRA will be supported by the Cooperation programme in areas where they constitute true European added value" (*EU Commission, accessed 12/2011 http://www.eubusiness.com/topics/research/FP7-objectives).

These are the aspects that are positively highlighted in the evaluation of all ETPs in August 2008 by IDEA Consult (IDEA Consult, 2008). However, when highlighting the poor performance indicators such as 1) low performance on market-regulated issues, they refer to i) addressing regulatory and other barriers to the optimal development, deployment and use of these technologies; and ii) identifying future education and training needs.

Such performance indicators indicate that the policy expectations for the ETPs go beyond serving as ‘instruments’ in project implementations of the next EU Framework Program.

Moreover, it does seem that EU policymakers may have tried to apply theory to practice, with the expectation that ETPs should evolve into participatory foresight processes with a design for wiring up innovation systems. However, I would argue that the evaluation report, even though it is based on surveys, the results are at an aggregate level, which will tell us nothing about the enticing characteristics of specific well performing ETPs or share an understanding of the specific ETPs diversity. This researcher therefore sets out on a journey into investigating more of this empirical context, in the search for novelty.

The empirical field studied in chapters 2 and 3 is the context of the roadmapping process for aligning European technology policy and industrial innovation. These efforts are explored within an analysis that departure at in innovation policy level and discusses the idea of innovation systems. It is an investigation into the role of the ETPs when applying roadmaps to the 2020 horizon for enhancing European innovation performance and competitiveness.

The research involves in-depth case studies of two European technology platforms, in wind power and in carbon, capture and storage technologies. These two platforms focus on the two technologies described in table 1.2.1.

Tabel 1.2.1. Platforms

Abbreviation:	**Issue:**	**Technology**
ZEP: European Technology Platform on Zero Emission and Fossil Fuel Power Plants	Reducing EU’s CO_2 emissions by 20% by the year 2020. Coal and gas power stations are currently the most energy effective and price competitive source of power.	Carbon Capture and Storage at coal and gas power stations – eventually also power stations using biomass
TPWind: European Technology Platform on Wind Energy	Increase in EU’s share of renewables of 20% by the year 2020. Wind power is currently the most mature and cost-competitive technology of renewable energy technologies.	Wind farms with special focus on offshore wind farms

Both technologies are seen by the IPCC panel, IEA and the EU Commission as technological solutions to climate change challenges. Wind is projected to play a huge role in contributing to reaching the EU targets for renewable energy of 20% by 2020, while CCS is part of the transition solution towards a sustainable energy system, as projections by the IPCC and IEA forecast that renewables alone will not ensure the 80-90% emission reduction (from the 1991 level) by the year 2050.

1.2.1.1 Innovation systems

The technological innovations system approach, also abbreviated as the TIS approach, has focused on the effect of networks on innovation, and therefore also on practical recommendation of performance measurements. In Bergek, Jaccobsson, Carlson et al.'s paper (Bergek et al., 2008) from 2008, there is a footnote obviously aimed at the critique of taking on a functionalistic approach to systems of innovation. Here, the footnote states that the term 'function' in relation to the innovation system is merely used to express the overall technical function of 'hard' system components serving as a function (p. 409). The components may then be referred to as the effects of an innovation system, or the outcome as a measure of a so-called well-functioning system.

A technological innovation system (TIS) was first defined as follows:

> "*A technological system may be defined as a network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilization of technology. Technological systems are defined in terms of knowledge/competence flows rather than flows of ordinary goods and services. They consist of dynamic knowledge and competence networks"* (Carlsson and Stankiewicz, 1991, p.111).

It was a new perspective, also focusing on evolutionary aspects in the characteristics of how that these systems develop. These characteristics are: 1) Entrepreneurial Activities, 2) Knowledge Development, 3) Knowledge Diffusion through Networks, 4) Guidance of the Search, 5) Market Formation, 6) Resource Mobilization, and 7) Creation of Legitimacy or Counteract Resistance to Change.

Recently, scholars such as Hekkert et al. (2007), Suurs and Hekkert (2009), and Hekkert and Negro (2009) have taken on the TIS perspective developing new approaches that examines these seven characteristics as functions of Technological Specific Innovation Systems (TSIS) in analyzing technological systems of innovations. This approach therefore focuses on the structural elements necessary for well performing TSIS. The positive feedback loop of system functions is what in TSIS-literature is called the motor. The perspective seems helpful in coping with establishing TSIS[1], leaving some sort of normative guidance.

However, this approach has received some criticism from the innovation system research community that its perspective is much too clinical, too normative (Lundvall, 2007) or lacks the dynamics of e.g. competing visions being static and comparative analysis with dynamic aspects only focusing on the emergence of new systems, new industries and not the changes from one system to another (Frank, 2005).

Although acknowledging the huge and important work of TIS or TSIS scholars (Carlsson and Stankiewicz, 1991; Bergek et al., 2008; Hekkert and Negro, 2009) in mapping overlays in innovation systems studies and guiding the search for performance measurements, there do also seem to be some discussion issues in defining what these functions entail.

Three important functions that are not simply straight forward in relation to the case studies in this thesis are:

- Entrepreneurial activities
- Knowledge development
- Resource mobilization

Initial studies of the two specific ETPs in Wind energy and CCS technology (elaborated in chapter two) do not normatively seem to live up to what is considered a well performing technological specific innovation system – and perhaps this is an add on to what makes them interesting cases - being the following issues around these three characteristics:

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[1] For further elaboration on how this critique is received, see Hekkert et al. (2007) and Suurs et al. (2009).

Entrepreneurial activities: Incumbent firms – existing large transnational firms – are the most dominating within both technological domains. TSIS theory says that these firms are often low on innovation performance – the most difficult to change; and that it is often small, up-start companies that show the highest performance in innovation. CCS, however, is a new emerging technology within coal-fired power plants. Yet, the actor-network of the CCS technologies seems to be dominated by large multinational energy utilities and oil and gas companies. No small companies seem to be involved in the high-level decision-making. This can be explained by 1) maturity of the technology, 2) size of the investment, and 3) market entry barriers. The technology is pre-mature: CCS is yet unproven on a commercial scale in Europe. However, the techniques have a history in the oil and gas industry, and CCS, on a commercial scale, will open up new market opportunities for the oil and gas industries.

These techniques are expensive, however, and investments in CCS demonstration cannot rely on public money alone, or on small and medium- size companies; large and well-established firms with solid investment capital are needed.

Knowledge development: From a strict theoretical point, there is no incentive for companies with superior technologies/knowledge to engage in R&D alliances, since they have more to lose than gain. Oxley (1997) points out that one mechanism for this is choosing an appropriate governance structure or organizational form. This is very interesting as it hits right on the nail one of the main issues in such cooperative constructions. They need to maintain an open knowledge exchange while yet avoiding leakage of valuable technology know-how. Or is the answer simply an exchange of knowledge – e.g. superior technology in exchange for knowledge of new complex markets?

One thing is sure, the knowledge development issue calls for further research understanding of this paradox – not just whether it happens or not, but also how it happens and why it happens – or why not.

Resource mobilization: For both platforms, there is a focus on demonstration plants, test facilities and cost reduction. There is no doubt that in both cases, the common vision has taken a commercial path, and that fulfilling it will be a major industrial and technological challenge.

Stakeholders define the Strategic Research Agenda, setting out the necessary medium- to long-term objectives for the technology.

The next step is for the stakeholders to implement the Strategic Research Agenda with mobilization of significant human and financial resources as stated in the Market Deployment Document. Joint Technology Initiatives or Joint Undertakings – driven by industries – are the next steps.

The results of the explorative case studies of the ETPs in chapter 2 (article 1) did show a stronger focus on:

- Involvement of multiple stakeholders.
- Bringing in the 'most important actors', hence strong involvement of firms, with the EU Commission stressing strategic aspects of R&D commercialization, because industry had been a missing actor group in the EU Framework Programs
- The social behavior and role of institutions through reference to relations among organizations, in contrast to technological determinism.
- Collaboration, using foresight as a tool to build consensus among stakeholders.
- Knowledge exchange and learning among stakeholders involving not only technical, but also social, environmental and economic aspects (related to public policy and public acceptance).

These are elements that go along with the idea of systems of innovation and, hence, add innovation policy to science and technology policies (Lundvall, B.-., Borras, S., 2006; Lundvall, 2007).

An overview of the theoretical development in thematic perspectives therefore seems relevant as to stress the importance of co-evolution in these perspectives.

Table 1.3.1. Rough overview of important developments in relevant thematic perspectives:

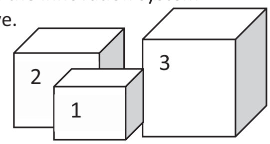
	1960 -1970	1980-1990		2000-2010	
Technology Foresight: (Cariola and Rolfo, 2004; Cagnin and Keenan, 2008,Johnston, 2008, Salo and Cuhls, 2003,Cuhls, 2003; Miles *et al.* 2008; Georghiou and Harper, 2011)	Forecasting of technological development. Expert views.	Focus on market failure, e.g. firms with short-term horizon = policy intervention	Foresight: includes input from social actors as the focus is on system failure, e.g. missing connection s = policy interventio n	Foresight: distributed role in science and innovation system	Foresight: mix of foresight concerns about actors and structure and includes broader social and economic issues
EU Policy paradigms: (Freeman, 1995,Freeman, 1996,Lundvall and Borras, 2006,Lundvall, 2007)	1.Science policy: Focus on R&D institutions and the production of scientific knowledge	2. Technology policy: Focus on advancement and commercialization of sectoral technical knowledge	3. Innovation Policy: Focus on overall innovative performance of the economy. Two versions: Picking the winner and the systemic version. Latter goes along with the innovation system perspective. 		

Table 1.3.1 illustrates the co-evolution of policy perspectives and the developments of rationales in foresight. The concept of science, technology and innovation policy (Lundvall and Borras, 2006; Lundvall, 2007) and the innovation system are further elaborated in chapter 2, serving as a theoretical framework for studying the evolving European Technology Platforms (ETPs).

1.2.1.2 Theoretical underpinnings to the idea of innovation systems

The evolutionary approach to innovation is that time matters to knowledge, as Brian Loasby (2001) says, and most important, that technological development is not technological determinism. Technical change is a process shaped by many entities. When digging deep enough in the literature of innovation systems, including the early writings of Lundvall, Freeman, and Metcalfe, it is found that the evolutionary approach is the theoretical underpinnings to the theory of innovation systems. At that time, in the 1980s, the policy was oriented towards national policy and thus national innovation systems. Originally, it was developed to counteract widespread neoclassic economic approaches that did not focus enough on the economic value of innovation and entrepreneurship – ideas that date back to the Schumpeterian idea of creative destruction, which could be, for example, to create new ways of production using more effective techniques that could produce more for less.

Metcalfe said in 1988: Technologies do not compete, only firms compete, "*and they do so by articulating a technology to achieve specific objectives within a specific environment*" (Metcalfe, 1988: 568). Technological development *is* largely embedded in social relations – in technology users, producers, and institutions that shape the development of collective frames around the meaning of new technologies (Kaplan and Tripsas, 2008). This is basically the solid argument for why the applied method studies in this thesis must be studied and further developed. We need to gain better understanding of technological development, innovation, and the embeddedness in social relations or the degree to which firms are enmeshed in social networks (Granovetter, 1985), by studying the applied contexts, applying the idea of innovation systems at the sector level and dynamics that goes on in the meso-micro processes.

1.2.1.3 Associated research questions and methods

The initial study of the ETPs points beyond both specific national and technological systems of innovation, since the ETPs encounter large transnational companies and also have the characteristic of being innovation policy tools capable of changing the institutional framework that is said to create technology-specific innovation systems. The ETPs are becoming more tools of an EU innovation policy that is trying to align EU policy with industrial innovation efforts. The conclusions of the first article therefore point to including a study into the evolution of the ETPs – where did they come from, and how did they evolve? Chapter 3 therefore adds structural analysis from social science to innovation studies, stressing the importance of relations as social entities in opposition to technological and material determinism (Granovetter, 1994, in Wassserman and Faust).

Chapters 2 and 3 are therefore complementary articles about how these new experimenting organizations work from within, creating new structures in the European economy and unfolding technological trajectories around specific problems. It is first of all an explorative study of the European Technology Platforms in wind energy and zero emissions from fossil fuel power plants.

Chapter 2

In the first article (chapter 2), I have formulated the following, more explorative research questions:

Chapter 2, RQ 1: What is the policy aim of the ETPs, and how is this reflected in their practice?

Chapter 2, RQ 2: Why do they emerge now (the context)?

I was curious to find the answers by exploring the referenced academic context of the European shift in policy paradigms: moving from science to technology policy, and recently towards a more inclusive innovation policy. The hypothesis was that ETPs are emerging as the notion of innovation systems is being adopted in EU policy practice.

Chapter 2, RQ 3: How are the ETPs characterized and what are their roles?

I therefore explore the context of ETPs in chapter 2. Explorative and expert interviews were conducted following a narrative approach to reconstructing the ETP processes of producing a European roadmap in specific technologies. In conducting this more explorative investigation, I used desk research, gathering key documents and identifying key players. This could be called a follow-the-actor-network research strategy, aligned with a narrative approach to re-construct the story of how the ETPs in wind and CCS emerged and their characteristics. The aim of the research was not to unfold the discourse on the ETPs, but to investigate their operation; therefore, I chose first to follow what seemed to be some of the key players, since the platform memberships also follow individuals and not organizations. Secondly, it also made sense to follow the key players because this knowledge is a cognitive process; it is in the heads of the individuals. The narrative approach combined with a strategy of following the key players was therefore chosen in order to perform the investigations inside the two platforms with interviews with individuals in key positions, i.e. the chairman and individuals pointed out as central players. Arguments for the necessity of the applied research method, rather than a competing alternative approach are presented in chapter 2's methodology section.

Chapter 3

The associated research paper presented in chapter 3 follows the study and innovation system approach described in chapter 1. Here, I deduce the hypothesis from theory of innovation systems and evolutionary economics that innovation systems are dynamic, and that innovation is about solving problems. Following the conceptual framework of dynamics, innovation system theory, and social network theory that economic interests are embedded in social relations, I apply social network analysis (SNA) using the software tool Ucinet 6 to study how connectivity changes in the two technology platforms over a four-year period. Two points in time are chosen: before and after the members had identified barriers to fulfilling the common vision and sector research agenda. The research question is:

> **Chapter 3, RQ 1:** If there is a change in the problem, does connectivity change in a way that makes sense in solving the problem?

To validate this analysis, I add a second research question that could either confirm or disconfirm the conclusion that the network is changing by adding a simple cluster analysis to the social network analysis and asking the question:

> **Chapter 3, RQ 2:** Are there any newcomers in the platform membership (Are they dynamic?), or are they more likely to become clubs and therefore less likely to be innovative?

The cluster analysis is based on the two platform networks at two points in time, and simply splitting the actors into a core and a periphery. According to Social Network Analysis theory, large networks feature a core and periphery structure. The core in the network may be seen as a dominating central cluster; compared to its core, the periphery has fewer connections. The core was therefore defined as those organizations that have a high frequency of interaction and often participate in the same events. Applying this core/periphery structure, the platform members or the organizations that they belong to at the two points in time were placed in two groups: the tightly interconnected group at the core or the relatively disconnected group at the periphery. The choice of research methods are justified and developed in a theoretical discussion based on the hypothesis in chapter 3, section 3.2: Theoretical framework; and the applied method and structure – i.e. the data matrix – is presented in chapter 3, section 3.3: Methodology and data.

Chapters 2 and 3 therefore comprise tightly related research regarding the story of the role of the ETPs in the structural change to a low carbon economy. The research is also a study of practice involving a new innovation policy tool and strategy making, as well as strategy implementation, through following the ETPs in wind power and zero emissions from fossil fuel power plants. Since the ETPs have now been in place for some time, these new institutional tools and foresight practices can be important influences for policy tendencies. Moreover, the first research paper presented in chapter 2 led in chapter 3 to a more evolutionary approach to capturing structural changes and industrial dynamics, which entails systems of innovation.

1.2.2 Firm level research

1.2.2.1 Defining commercialization and technologies

In the following, the commercialization of technology refers to the process of determining when a technology is ready to be introduced to the market and implemented in a commercially viable product. This part of innovation may be overlooked in theory, but not in applied business practices. For companies to remain competitive, innovation and new technology should be a means of introducing product features that differentiate one product from other available products. The value of this perspective lies in the distinction between technology and new products:

> *"A technology is essentially a 'capability', often a versatile one that can be used in more than one product. Products are occasionally embodiments of this capability and mediate the process of bringing it to market and realizing value from it*" (Jolly, 1997) (p. xv).

A commercialization strategy is therefore a company's focus on a technology's development phases toward a mature technology that is ready for introduction to the market, where the company can thus profit from its technological innovation.

Commercialization can thus be regarded as the investment aspect of R&D – i.e. commercialization is a strategic perspective on an invention's early innovation phase. The stages of technology development typically begin with an exploratory phase focusing on ideas, followed by a funnel process in which a few selected ideas are matured and their paths toward market introduction are described, which leads to the development of a commercialization strategy for the given technology. In the process, key stakeholders, goals and milestones are identified. Frequently, market surveys, customer analysis and customer involvement analysis are also included (Cooper, 2006). However, despite the broad array of analyses and idea maturation, very few technologies make it to the actual commercialization stage and are successfully introduced to markets (He et al., 2008; Jolly, 1997). Thus, bringing technologies to market and creating viable paths for such commercialization to occur are both valuable parts of the innovation phase. Explaining examples and concepts of how different methods of gathering intelligence can be matched to the specific needs of e.g. a group of experts can provide practitioners with a better understanding of how roadmapping can be configured to match participatory processes and be transformed from a heavy strategic tool to a more easily operated method.

1.2.2.2 Dynamic capabilities

Dynamic capabilities denote certain routines or practices addressing the firm's ability to renew its resources and adapt to changes in the environment (Barney et al., 2001; Barney, 2001). Such capabilities therefore include the scaling up of the firm's ability to redirect resources in order to seize business opportunities. Allocation of resources is essential in order to direct them into the most promising avenues, while excluding less viable technologies. This redirection of resources can improve the firm's ability to react and adapt quickly to changes in the strategic environment.

In its purest sense, the term *dynamic* refers to a company's ability to shape and renew itself in response to changes in the market environment. The term *capabilities*, on the other hand, relates to assets, resources and competences. These must be developed dynamically to meet the requirements of the changes that occur in the market environment (Teece et al., 1994). Thus, it can be stated that *dynamic capabilities* are future-oriented processes, whereas capabilities (assets, resources and competences) are static and relate to competitive advantages in the present (Teece, 1986) in the same way that complementary assets relate to present commercialization in actually *profiting from technological innovation (*Teece, 1986). A company needs *dynamic capabilities* to change its present capabilities (assets, resources and competences) and adapt to the future. The key mindset of dynamic capabilities theory is that a superior technology is rarely sufficient to sustain competitive advantage in the market.

The dynamic capabilities approach, as summarized by Teece (2006) and rephrased slightly by Augier and Teece (2009), deals with three separate types of processes that a company must be able to perform: Sensing, Seizing and Reconfiguring.

Sensing deals with the ability to understand what will come, whereas *seizing* relates to the framework for *profiting from technology innovation,* i.e., for fulfilling the entire potential of the current situation. The term *reconfiguring* is the key to dynamic capabilities, because it relates to the processes needed to change the resource base of the company to adjust to upcoming conditions.

In summary, dynamic capabilities deal with the processes that allow companies to sustain competitive advantages in fast-moving technological environments, given their history and current stage of development. Dynamic capabilities are therefore distinctive processes that facilitate not only the ability to recognize technological changes in the market environment, but also the processes of changing and shaping the company's asset positions in response to change. Although the foundations of dynamic capabilities approaches are well established, Ambrosini and Bowman (2009) recently argued that further academic studies in the field are needed. In particular, they note that scholars should pursue the possibility of linking dynamic capabilities to related fields of study, and that case studies should be performed to identify and understand the nature of dynamic capabilities within specific industries. Is it, for instance, the existence of a given asset type, or the methods employed to foresee future development, that is more important for generating competitive advantages?

1.2.2.3 Associated research questions and methods

Addressing the initial gap between theory and practice: if roadmapping is a method, which theory is it then grounded in? And addressing the more practical issue when dealing with a specific technology and specific needs of a company: what would be the bridge between roadmapping as a method and dynamic capability as a perspective based on strategic management resources? Presumably, the link is the complementary asset identification method, a somewhat novel method developed in chapter 5 for the roadmapping process used by Novozymes in the Albufuse® Flex project and further developed and discussed in chapter 5's theoretical framing presented in section 5.2.4.

In the academic literature, we (co-author and I, in chapter 5) found only limited studies of practical application of roadmapping in biopharmaceutical firms. The hypothesis that forms the basis of this study is therefore derived from these challenges. In particular, it is hypothesized in chapter 5 that companies could improve their knowledge base by introducing a practical exploratory roadmap method that is integrated with a complementary asset identification method. This approach would enable the companies to make better decisions about whether a technology is suitable for commercialization, what sorts of capabilities are needed and which complementary assets would be needed for its commercialization. Although strategies for the commercialization of technologies are an important driver in innovation systems, an applied model for explorative roadmapping that is integrated with dynamic capabilities does not yet exist.

Chapter 4

Chapter 4 is a practical guide focusing on providing a small novel contribution to academic and primarily the foresight practice community. It provides a theoretical framework for combining the foresight methods of scenarios with roadmapping at firm level. The workshop guide deals with a simple question (somehow a research question):

Chapter 4, RQ 1: How to combine scenarios with roadmapping?

Provided with an argument of what the added value then would be, the answer is simple: While scenarios open up to possible futures, the roadmapping framework forces us to choose the most important drivers, identify risks, and prioritize between R&D and the possible routes from the present to the desired future, which is embedded in the so-called common vision. It provides a guide to a simple exercise deduced from theory but applied in a workshop context.

Regarding the method applied, the guide was tested in a workshop consisting of 25 lead specialists within a large, globally operating engineering company. The context had to be omitted due to confidentiality, but it was useful, and the context clearly showed that the formulation of the common vision can serve as the bridge when combining these two methods – moving from scenarios that open up to uncertainty with regard to an action plan into a funnel of prioritized R&D.

Chapter 5

Chapter 5 consists of the fourth and final research paper in the thesis and explores how roadmapping, integrated with dynamic capabilities, can be a systemized tool for gathering intelligence in strategic processes of path creation for a new drug delivery within the biopharmaceutical industry.

A conceptual framework is established based on referenced academic literature for exploring the practical usage of roadmapping for the strategic planning of commercialization processes, in this case, for engineering the roadmap for the Albufuse® Flex technology, which is a half-life extension drug delivery. Such detailed roadmapping processes within a firm are rather rare in academic literature, which is possibly one of the reasons why its terminology is widespread in contrast to its systemic framework. The systemic framework and participatory strength lies in communicating technological development in ways that create strategic dialogue and facilitate long-term business planning. Thus, the overall broader research question explored in this study asks:

> **Chapter 5, Overall RQ:** How could explorative roadmapping integrated with dynamic capability thinking be applied in practice?

Such a model could enable a company to have a systematic yet flexible framework that provides it with a strategic overview of its innovation capabilities, even for initiatives that are already in the pre-design phase.

The investigation presented in this work implements the theoretical notions discussed above in a real-world test case, thereby allowing a practical assessment of the use of strategic roadmapping for commercialization analysis. Specifically, this study considers the case of Novozymes A/S, a large biotech company that is currently moving into the biopharmaceutical sector with a number of new products. Among these products is a novel drug delivery solution, a second-generation albumin fusion called *albufuse*$^{2.00}$ at the time we were first introduced to it.

The case-based research questions are organized along the three phases of analysis. The first aims at acquiring an initial understanding of the promising emerging field of biopharmaceuticals along with delivery of biologically based medicines.

> **Chapter 5, RQ 1:** What are the trends and drivers of the Albufuse® Flex? (the strategic landscape)?

The case study is based on research conducted in close dialogue with the senior director from Novozymes using both expert interviews and workshops. It appeared that participatory processes using workshops can be a challenge as to face the risk that managers are reluctant to share key information in workshop settings. It was therefore necessary to counter this risk when applying participatory elements in the data gathering by conducting interviews with key managers in Novozymes prior to a larger workshop that then concerned more specific tasks such as identifying product features and valuating attributes. After the study, and an exclusive interview with Senior Director of Novozymes' Biopharma was conducted to reflect upon the application of strategic roadmaps. The interview was based on a semi-structured interview guide as recommended by King (1994; 2004).

At the time of the research taking place, the firm was only considering entering this field. This was due to many factors such as being a fairly new niche player in the pharmaceutical industry, and that the field lies outside the enzyme business that the firm traditionally specialized in.Therefore, the firm has a huge path dependency, which impedes entrance into this new industry. The firm can only rely on its biotechnical capabilities and experience to expand into other business areas with high growth potential in order to ensure long-term business opportunities. The questions of relevance are therefore:

Chapter 5, RQ 2: What are the complementary assets needed to achieve successful commercialization?

Chapter 5, RQ 3: But foremost, how to identify them? What methods and data are available?

These final questions are answered in chapter 5, where methods and data are presented in the project outline. The final issue of understanding the outcome of this multi-level analysis is then discussed in chapter 6.

1.3 Thesis outline

This thesis explores two research tracks in roadmapping: one at the sector level, studying these new contexts of applied roadmapping, and another at the firm level, mainly focusing on the identified challenges – primarily that of moving from theory and methods to customizing the roadmap process to the specific needs of the firm and industry in question.

Figure 1.3. Outline of the thesis

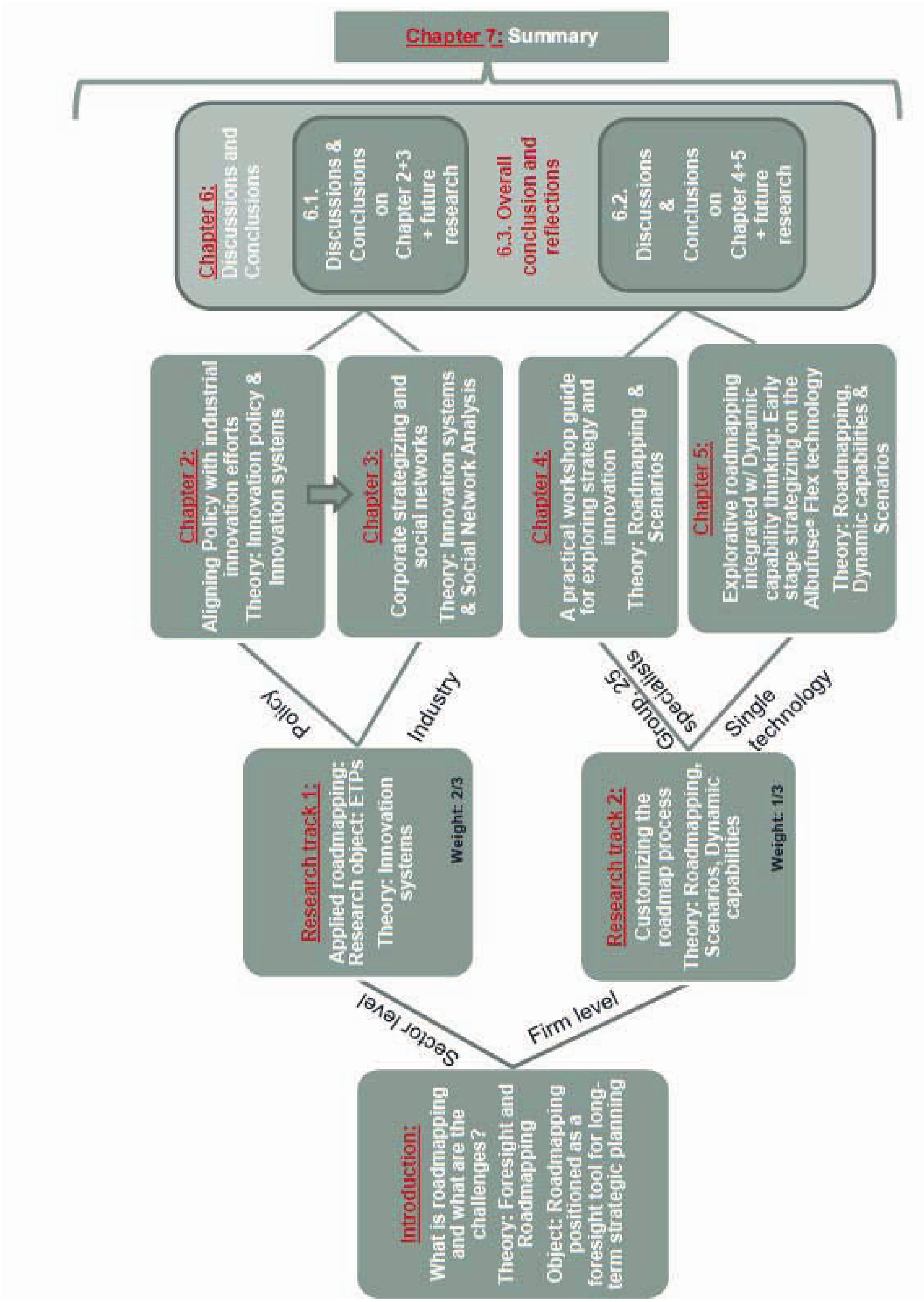


Figure 1.3 illustrates the outline of the thesis, which consists of seven chapters, including an introduction, four accepted research papers, a discussion and conclusion chapter, and a summary.

Chapter 1 serves as the introduction to the thesis with the aim of providing a clear and well-composed frame around the articles. Chapters 2 to 5 consist of the research study included in the four research papers currently in different stages of academic publishing.

Writing an article-based thesis, in contrast to a monograph, is a challenge in relation to providing a coherent thesis. More than twice, I experienced that my extended abstracts were not among the accepted conference contributions. Although such experiences caused changes to the original master plan, new opportunities arose for other conferences. Whether it is a conference paper or a research paper to be submitted to an international journal, all research papers need to be fitted to the current topic and relate to the relevant academic literature. Eventually, the three research papers presented in chapters 2, 3 and 4 were presented at conferences. The last research paper in chapter 5 has not been presented at a conference due to a confidentiality process. However, with written permission from Novozymes's Senior Director of Biobusiness, it has been submitted directly to *Technological Forecasting and Social Change*, and recently gone through a review process by a US editor and two anonymous reviewers, who provided what can be considered a valuable and acceptable recommendation for a revised version before publication.

The thesis outline is therefore my best attempt to create a coherent structure based on the four research papers from the period August 2009 to January 2013 and currently in different stages of academic publishing.

The four research papers are aligned with two research tracks, one sector-level research track comprising chapters 2 and 3, and one firm-level research track comprising chapters 4 and 5. Chapters 2 and 3 are mainly policy-oriented research carried out at the meso level with focus on how theoretical ideas of innovation systems are implemented in practice, and on understanding the context of the roadmapping processes in the industry-driven ETPs in wind power and CCS.

Chapters 4 and 5 are conceptual and related to processes at the firm level focusing on development of new conceptual tools for communicating the value of technology between collaborative groups. And finally, chapter 6 provides the overall conclusions, including discussions and considerations about further research, while chapter 7 provides the summary and closing remarks.

Chapter 2

The explorative studies in this thesis not only seek insight into applied foresight, but mostly also how theoretical ideas of systems of innovation and participatory processes are dealt with in practice. The study draws conclusions regarding characteristics of the new innovation policy tools, the ETPs in wind energy and zero emissions from fossil fuel – their rationales, organizational structure, interests, and characteristics of key stakeholders. This was the objective in the first article. The article is currently being re-submitted to the international journal, *Science and Public Policy,* after being revised according to the recommendations by Editor Dr. Sybille Hinze, which are based on comments from two anonymous reviewers.

Chapter 3

The second article's aim was to investigate the dynamics of the actor network while exploring the idea of systemic innovation, and thus the impact on policy of such new practice. The analogy of a system of innovation as an open system was used in a detailed study of two technology platforms. Social network analysis (SNA) methods were undertaken to map and compare the two technology platforms at two points in time in order to understand how they have changed and evolved. The paper was presented and published in the proceedings of the 14th International Schumpeter Society Conference, and invited for submission to a special issue of the journal, *Evolutionary Economics*. The author submitted the paper for publication on 15 October 2012, and it is currently in review.

Chapter 4

The thesis includes a published European Foresight Platform brief, a practical workshop guide to combining future scenarios with the action-oriented roadmapping process in order to explore strategy and innovation. The outcome is based on experience from producing a guide for a one-day workshop for 25 leading specialists. Due to confidentiality, the specific scenarios are omitted, and the brief is discussed at the theoretical level.

Chapter 5

This chapter includes a conceptual framework for roadmapping and dynamic capabilities, applied as a corporate foresight framework in Novozymes for creating the path for delivery of a new drug. This work resulted from an opportunity to supervise a master thesis in collaboration with Novozymes Bio Business between September 2010 and April 2011. The result is an article focusing on methodology that combines technology roadmap with theories of dynamic capabilities from the strategic management literature. No such attempts to combine the roadmap approach with dynamic capability thinking exits in current literature. One explanation could be the need for confidentiality in relation to firms' strategic planning processes; another explanation emphasized by scholars is the flexible nature of roadmapping – the demand for customization may make companies reluctant to engage in roadmapping processes (Phaal and Muller, 2009; Phaal et al., 2003).

According to the senior director of Novozymes' biobusiness, the research study, the roadmap, capability maps and use of scenarios has had great impact on Novozymes' decision-making in path creation for Albufuse® Flex, possibly moving the firm into new markets for biopharmaceutical drug deliveries. Furthermore, in February 2012, the firm's Albufuse® Flex received the Drug Delivery Partnership award in Las Vegas for being the most promising technology of the year. The article is currently being revised according to the recommendations of the US editor, Dr. Tugrul Daim, and two anonymous reviewers for the international journal, *Technological Forecasting and Social Change*.

Chapter 6

The research in this thesis supports elements of an emerging evolutionary research agenda in foresight and innovation studies. Economic interest is embedded in social relations, and foresight studies are embedded in long-term strategic planning, which is based on economic interests. Participatory processes distinguish foresight from forecasting. Roadmapping does provide a structured framework and a systemized approach, identifying and gathering stakeholders in aligning strategic goals with industrial innovation efforts. These conclusions are discussed in chapter 6. Moreover, the study has initiated the quest for more research in this direction, research that will provide theoretical underpinnings for foresight processes and for roadmapping, so that it can serve as a hub that connects research and practice. This would provide better frameworks, and also theory, and lead to better understanding of social factors beyond standard deviations. These issues are outlined in chapter 6.

Chapter 7

The final chapter provides the summary of the thesis.

1.4 Data sources

Chapters 1-3: Data in the initial phases of the ETP studies at sector level in how strategic research agendas and common visions are created are based on the European Commission's documents on the ETPs and the two specific technology platform's website. These data are used in the analyses in chapters 1 and 2.

Key documents of ZEP and TPWind:

These include the common vision documents, the strategic research agendas (SRA) and the strategic deployment documents (SDD) of the TPWind and ZEP platforms. These were accessed through the platforms website, and the website of the European Commission.

Explorative interviews:

This platform data was then supplemented with data gathered from explorative interviews with key members of the European Technology Platform in Zero Emissions – the ZEP technology platform. One of the main sources here was the explorative interview with the expert in the geological study of carbon storage technologies, the CEO from Vattenfall, Niels Peter Christensen. From TPWind, the main explorative interview was with wind technology expert, Peter Hjuler, from DTU Wind, Technical University of Denmark, who gave first-hand insight into the data I needed to collect.

Interviews at the General Assembly of the Platforms:

Data from key documents were supplemented with face-to-face interviews with key stakeholders representing EU policy makers, the research and business community of ZEP and TPWind. The expert interviews were conducted using a semi-structured interview guide for gathering data in a more systemic manner when identifying interest and barriers in relation to bringing these technologies forward (the guide is appended to chapter 2, in section 2.12). Data from these interviews were gathered during my participation in the General Assembly (GA) of the two platforms during 2009-2011 (see section 2.3.1 for the dates of GAs in the specific platforms).

Data on membership of ZEP and TPWind

Data on individual members of the two specific platforms during start-up, the first organizational outcomes with steering committees and working groups, and up to the latest data on how the platforms are organized today were gathered from different sources, and pieced together:

Sources:

- The platforms' secretariats provided recent membership lists.
- Data on Steering Committees of TPWind, Advisory Council of ZEP, and organizational structures of ZEP and TPWind were gathered from key documents of the two platforms: The common vision, the

Strategic research agenda, and the market deployment document.

- Data on working groups in TPWind were collected through the TPWind secretariat, EWEA.
- Data on membership of working groups and a taskforce group appointed later in ZEP were gathered through access to minutes taken of these meeting during 2005-2012. The data I needed on membership before the appointment of the ZEP secretariat was handled by Triarii BV. However, minutes, attendance lists and other documents, after the transformation to taskforces, were available at the member section of ZEP's website: www.zeroemissionsplatform.eu, to which I was granted access.
- All data were cross-checked in order to validate my data, using these different sources.

Going through all these sources, I ran into missing data on who were the members of ZEP's Working Group 3, "Infrastructure and Environment", in November 2006. By investigating key documents, I was able to gather some data on the chairman from the Bellona organization and some members of this working group. The working group data were then gathered through personal correspondence with the chairman via email in order to fill in the missing information on additional members. The preliminary list of members was made on the basis of existing minutes, and thereafter cross-checked with the chairman in order to validate my data.

The membership data structured by name of organization was then entered on Excel data sheets, which revealed missing names of firms or non-exiting organization names. This was then investigated through Google searches and Wikipedia to capture the history of mergers.

All these data were double checked with minutes taken from steering committee and group meetings accessed through ZEP's and TPWind's websites before I achieved a complete data set for the two platforms at two points in time. This provided data for a social network analysis of each platform, TPWind and ZEP, over a four-five year period. This analysis is presented in chapter 3 (second article).

<u>Chapter 4:</u> The data here were gathered in an iterative process with point of departure in theory, but also using our teachingexperience – Senior Researcher Kristian Borch, in scenario-making, and I, in roadmapping. The concept was tested in practice at a one-day workshop that included 25 engineers who were recently appointed "lead specialists", and later tested in one-day workshops for PhD students.

<u>Chapter 5:</u> One of the initial steps was to collect data and information in order to understand the strategic landscape of and identify the complementary assets that were needed to achieve successful

commercialization. This information was gathered through expert interviews in Novozymes; and later, from expert panels and in-house workshops consisting of scientists from R&D and management experts from marketing and risk management, which comprised the second major phase of the case study. The third and final phase was the interpretation and analysis of data and information, which led to the development and execution of the roadmap. Scenario was used to highlight four possible directions, or four possible futures – one was developing a drug delivery platform; another was selling the license; while the remaining two were based on business as usual.

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2. Chapter two: Aligning policy goals and industrial innovation efforts: European Technology Platforms in wind and CO_2 capture and storage technologies

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* [2] Lykke Margot Ricard, Technical University of Denmark, Department of Management Engineering,

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Abstract

This paper investigates a new type of organization in the European Union (EU), namely the European Technology Platforms (ETPs). Recently, 36 industry-led ETPs have emerged within many technical areas. The hypothesis is that the ETPs play an important role in outlining the trajectories of EU technology policy making. The study was limited to examine two topical platforms: The European Wind Platform and the Zero emissions platform. Results confirm that boundaries for strategizing and prioritizing are no longer constrained by technocratic traditions in

[2] Lykke Margot Ricard, lmri@man.dtu.dk, Technical University of Denmark. Department of Management Engineering. Produktionstorvet, Building 426, Office 033, 2800 Kgs. Lyngby, Denmark, Phone (direct) +45 45257140.

EU policy-making but have been expanded along the introduction of innovation policy to engage stakeholders representing both science and industry. This institutional change is co-evolving with the emergence of new organizations and policy processes that mobilize industry to increase the rate of technical change though R&D investment and thus aligning policy goals and industrial innovation efforts. Hence, the paper develops a model that illuminates this new policy tool, and illustrates the communication process of the new technology between the macro, meso and micro level.

2.1. Introduction

Since 2001 when the EU Commission supported the establishment of the first European Technology Platform in aeronautics, the number of European Technology Platforms (ETPs) has increased to today's number of 36 industry-driven platforms. The largest increase was in the area of energy technologies, and this increase happened concurrently with the mid-evaluation of the Lisbon strategy. The original Lisbon strategy of the European Commission, which was formulated in 2000 and had a time span of 10 years, set the goal of making the EU: *The most competitive and dynamic knowledge-based economy in the world by 2010, capable of sustainable economic growth with more and better jobs and greater social cohesion and respect for the environment.* – Lisbon declaration, 24 March 2000

This strategy highlighted the concept of the knowledge triangle to ensure better interaction between three key drivers of a knowledge society—research, education and innovation. However, the mid-evaluation of the Lisbon strategy in 2005, which included a wide range of consultancies with experts and the public, reflected a failure to achieve this goal. It found that Europe was falling behind its competitors and that R&D was leaving Europe (Deroose et al., 2008). The Lisbon strategy was also criticized for devolving into complex goal setting and confusion regarding the division of responsibilities between the EU and its member states as well as internally within various EU institutions (European Commission, 2010). To address these issues, the Lisbon Strategy was re-launched, reducing the number of goals while maintaining the goal of dedicating three percent of the GDP to investment in R&D (Johansson et al., 2007). Additionally, this strategy included a new role for the European Commission that transitioned it from a largely administrative role towards a political role (Borras, 2009).

This introduction sets the scene for investigating the emergence of the ETPs. An introduction to the ETPs and their contextual setting may explain why these new forms of collaboration emerged at this point in time. Inspired by Vanberg (2011) and his J. R. Common's perspective that institutions are the creation of purposeful design, institutions may be seen as phenomena of accumulated knowledge, including what has worked and what has not. If these institutions create undesirable consequences, we create new solutions in the form of new institutions (Vanberg, 1997; 2011). The investigation draws on this form of reasoning and on previous theoretical and empirical work on policy perspectives.

The European Technology Platforms are an instrument of European innovation policy and since they are in place now for some time, it is appropriate to analyze them in terms of key institutional characteristics. The hypothesis is therefore very simple that since the ETPs are now in place they have developed key institutional characteristics, assuming that they have formed a rationale, an organizational structure, a selection mechanism on the recruitment of new members, and a mechanism for implementation of strategic research agendas. The theoretical question using the concepts of innovation systemic is what can it tell us about the rationality, organizational structure and mechanism of a new innovation policy instrument as the ETPs?

The concept of technological innovation systems could then be the obvious choice when looking at technological developments and synergetic clusters of firms and technologies giving raise to new business opportunities (Carlsson and Stankiewicz, 1991). But this perspective on the ETPs does seem to narrowing it down to much, as the ETPs are so much more than technological clusters. In this context the ETPs are important instrument of European innovation policy and since they are in place now for some time, it is appropriate to analyze them in terms of key institutional characteristics, but moreover how they are not only designed to align industrial innovation effort with policy goals, but also to influence the policy at the supra national level as well as influence the policy of the member states. The analysis of the ETPs therefore empirically addresses a gap in the literature of innovation systems: Indeed innovation needs to be seen in relation to the role of institutions, and technological systems are said to be defined by the institutional frame. However, the ETPs members are perhaps evolving from technological networks, but as institutions the ETPs are not only technological systems. Naturally, they are not national, but are they European? They are new innovation policy tools focusing on the overall innovative performance of the economy, and currently highly influencing the EU technology policy and strategies by having delivered 2020 roadmaps as part of the SET-plan's information system. The ETPs must therefore be more as capable of changing the institutional framework that scholars of technological systems has said is what defines the technological systems. This gap therefore calls for illumination of how to perceive the ETPs in the interplay between micro and macro processes using the ideas of innovation systems on how knowledge evolves through processes of learning and innovation {{192 Lundvall,B.-Å. 2007}}. Where the term 'system' is not referred to as a something mechanic, neither in public policy as something that can be created or managed, but more in term of what theory is supposed to do, to organize and focus the analysis, providing a set of lenses, and seeing the research object that could not be understood without these ideas. This is the contribution that this author wishes to make. The study is limited to two platforms involving mature wind power technologies and the emerging CCS technologies. Both technologies are recognized as key technologies (capable of increased competitiveness*)* for a transition to a low-carbon economy in the strategic energy technology plan (the SET-plan). In the context of the ETPs' emergence, the policymakers and stakeholder seems to create new roles in the alliances between industry, university and government, similar to a triple helix alliance (Etzkowitz and Leydesdorff, 2000; Johnson, 2008), which could be a vis-à-vis competing alternative. However, the author chooses to follow the ideas of the innovation system, which is attractive because it focuses on the connections within boundaries and includes the roles of many players, not limited to only those three categories. The analytical framework is then set within an innovation policy context related to ideas of innovation systems, which seems to have been co-evolving with policy perspectives moving from science and technology policy towards a focus on innovation policy (Lundvall and Borras, 2006).

The next section therefore presents a brief theoretical discussion of the perspectives of science, technology and innovation policy, innovation systems and the roots of evolutionary growth theory (Nelson and Sampat, 2001; Nelson and Winter, 2002; Nelson, 2002), providing insight into the theoretical perspective on innovation policy and how the current literature characterizes its instruments. The section is followed by the case analysis of the ZEP and the TPWind, followed by findings, discussion, and conclusion section, as well as the study highlights new areas for further research.

2.2. Innovation policy and innovation system thinking

Many scholars have focused on why changes should be made in the current energy system, and what changes should be made to build a sustainable future. One thing that scholars agree on is that the transition to a sustainable energy system means changes in more than one system and requires governments to navigate across complex networks of players, existing production systems and institutions (Smith et al., 2005; Smith and Stirling, 2010). As Freeman noted in 1963, technical change relates to many interrelated factors: education, training, design, engineering, and production (Freeman, 1979; Freeman and Soete, 2009). Systemic thinking and innovation policy bring the members of the industrial business communities, which have been left out of policy discussions, into play again. Alternatively, these members may have isolated themselves to minimize the risk of leaking superior technology to their competitors. However, customer-driven innovation, open innovation, corporate social responsibility, globalization, which caused cutbacks in core business during the 1990s along with possibilities for out-sourcing and new markets (Edler, 2008; Sachwald, 2008), and the economic crisis have caused companies to focus on a smaller core, yet a larger periphery, which involves partner networks in every aspect of the company, from supplier to innovation.

Within the last decade, EU policy has changed its political instruments and perspective from science to technology policy and most recently from science to innovation policy as argued by Lundvall (2007) and Lundvall and Borras (2006). These policy perspectives resemble Chinese boxes, where innovation policy is the largest box. The difference between traditional science policy and technology policy is characterized by a more instrumental focus on national prestige and economic objectives, but with the same elements, such as universities, research institutions, technological institutes and R&D laboratories. Technology policy has a wider focus on the advancement and commercialization of sectorial technical knowledge, e.g. the linking of universities with industry. Thus, the commercialization of technologies is a step towards an innovation policy perspective. A great difference lies in a broader focus in an innovation policy perspective: from a focus on the university and technology sectors to a focus on overall innovative performance, which includes the business communities.

Setting R&D priorities is a very important factor and is widely recognized as an important instrument for structuring change, but it is not the only instrument. Technical change depends not only on R&D, as Christopher Freeman noted in 1963 (Freeman, 1995; Freeman and Soete, 2009), but also on many related factors such as education, training, production engineering, design, and quality control. Freeman was one of the architects behind the “Frascati Manual” (OECD, 1963), which provided the OECD and political institutions with methods to measure R&D and allowed for comparisons across countries. Freeman (1995) states that the authors of the “Frascati Manual” have since noted a critique of the methods that endorsed the linear innovation model and overlooked the feedback mechanism from the market and production into the R&D system: *The simple fact that the R&D measures were the only ones that were available reinforced these tendencies...* (Freeman, 1995:6). Moreover, he argues against endorsing the linear innovation model and provides empirical evidence against it:

> *Numerous case studies of innovation brought out the importance of flows of information and knowledge between firms as well as within firms. Moreover, the results of the empirical research pointed to the importance both of flows to and from sources of scientific and technical knowledge and of flows to and from users of products and processes* (Freeman, 1996:30).

Innovation policy and innovation systems seem to have a mutual historical development with an explicit shift in perspective from systems of production towards systems of innovation. In 1987, Freeman used the expression: “The national system of innovation”, which he defined as follows: *The network of institutions in the public and private sector whose activities and interactions initiate, import and diffuse new technologies* (Freeman, 1987:1).

The concept of the national innovation system had been developed for twenty years in parallel by Christopher Freeman at SPRU, Sussex University, UK, and the IKE group at Aalborg University, Denmark (Freeman, 1995; Lundvall et al., 2002). Their perception of innovations contrasted with the economic policy perception of international competiveness as static measurements of nominal national wages and nominal values of currencies. A central focus of the processes was on innovation and learning (Lundvall, 2007). This concept was further developed and expanded by Bengt-Åke Lundvall’s publication in 1988 of the idea that innovation as an interactive process: from user-producer interaction to the national system of innovation (Lundvall, 1988).

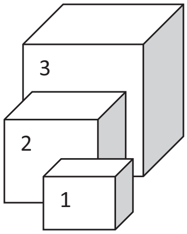
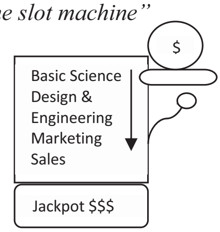
The evolutionary economic concept plays a significant role in the innovation system perspective, which rests on the economic concept of a selection mechanism that stands in opposition to neoclassical economic theories. According to Nelson (1995), the neoclassical growth theory has been constrained by its basis on mechanical concepts of equilibrium (Nelson, 1995), whereas an evolutionary economic theory builds on uncertainties, expectations and a ‘systematic selection mechanism’, which leads to a broader understanding of what is actually happening at the micro level to understand the various levels of aggregation; moreover, it builds on technological developments as an endogenous growth factor (Nelson and Winter, 1977; Lundvall 2007). The innovation system is a theoretical concept within evolutionary economics. It allows us to see the variations among firms and in the technologies (Nelson, 1995:71).

In the last chapter in the Handbook of Innovation, Lundvall and Borrás (2006:615) argue that an innovation system perspective is an interactive process focusing on competencies between suppliers, users, knowledge institutions and policymakers. It provides heterogeneous perspectives on the role of innovations, dynamics and transformations, and therefore also naturally develops insights into why best practices cannot necessarily be transferred from one context to another. Since the national innovation system was introduced, scholars have introduced regional innovation systems, sectorial systems of innovation and technological innovation systems (Edquist, 2005). A technological innovation system was first defined by Carlsson and Stankiewicz (1991) and later developed into an approach that looks for seven functions and focuses on the structural elements necessary for a well-performing system (Hekkert et al., 2007). This approach was criticized by the innovation system research community (Hekkert and Negro, 2009) on the grounds that its perspective is much too functionalistic and omits the social shaping by the players in the innovation system leading to a lack of dynamics. However, in the research presented here, the actors, who have competing visions, expectations, networks, capabilities and resources, are close to what Freeman, in his article on “The greening of technologies and models”, and refers to as mobilizing human capital combined with R&D investments to create change towards growth and the greening of technologies.

A rough overview highlighting some of the mentioned changes in thematic perspectives are outlined in table 2.2 along with changes in innovation models, governance tools along complex public-private partnership models, and the developments in systems of innovation.

Table 2.2. Rough overview of changes in thematic perspectives

1960 -1970 | 1980-1990 | 2000-2010

Transition from Government to Governance: (Stoke, 1998; Smith et al., 2005; Smith and Stirling, 2007; Zeitlin, 2008)		Increase in Governance tools: political strategy making in interaction between non-governmental actors, firms, private-public partnerships and quasi-governmental boards.	
EU Policy paradigms: (Lundvall and Borras, 2006; Borras, 2009) 	1. Science policy: Focus on R&D institutions and the production of scientific knowledge.	2. Technology policy: Focus on advancement and commercialization of sectorial technical knowledge.	3. Innovation Policy: Focus on overall innovative performance of the economy. Two versions: Picking the winner and the systemic version, the latter of which follows the innovation system perspective.
Innovation perspectives: (Kline and Rosenberg, 1986; Freeman, 1987;1995;1996; Lundvall, 1988; 2007; Carlsson and Stankiewicz, 1991; Lundvall et al., 2002; Edquist, 2005; Freeman and Soete, 2009).	Linear model: *"The slot machine"* 	Chain-linked model, feedback-mechanism from market and production in the R&D system. User-producer and systemic thinking in opposition to the linear model. The development of the National innovation system perspective.	Innovation systems: National, Regional, Technological systems of innovation, Sectorial systems of innovation. Innovation is more than technological innovation.

These various innovation system perspectives can be viewed as a set of lenses focusing on the central viewpoint: a technology or a sector linked to a technological domain. Each perspective focuses on different aspects of the innovation systems and comprises a model that gives meaning to what we see and experience. The choice depends on the question being asked. In this case, we are considering the EU's multi-level policy and a European R&D system, which consists of different subsystems; thus, a perspective cutting across many systems, is the most informative, thus the NIS approach focusing on a European Innovation system perspective emerging from the European Commission's initiative, assuming it continues this more active political role.

2.3. Methodology

The framing for the roadmap processes was found in the literature on a changing institutional context in which the government becomes the host of governing bodies. The innovation policy perspective, which focuses on innovation and competitiveness, includes the industrial and business communities as stakeholders. It is clear that when gathering different stakeholders, including business competitors, it is necessary to form some sort of empowerment because the players may have conflicting roles and interests. Finding structure and defining roles and targets in a negotiating process is not easy, as the process lies in the minds of the key stakeholders who are leading the platform. The methodology is therefore not a strictly evidence-based approach, but a narrative approach, which seeks to tell the story behind the roadmap processes to form the body of roles and powers that define the technology path that is now laid out in the specific European roadmaps in wind and CCS.

The narrative approach

The analytical framework for the reconstruction is inspired by Michel Callon's *Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay* (Callon, 1986). The structure follows the four elements of an approach that translates a study of power: *problematization, interessement, enrollment and mobilization*. The four elements compose the structure chosen for presenting the stories for two important reasons: first, when focusing on a proposed problem of a technology or barrier to bringing R&D to the market, it is relevant to ask whom does it concern, and second, it is important to ask who is proposing the relevance (Jørgensen et al., 2009). The vis-à-vis competing alternative to the narrative approach could be to form a discourse analysis based on positions and demarcation criteria i.e. profit/non- profit, influence/non influence or knowledge sharing/not knowledge sharing. However, in the two platforms there are 200 individuals in the ZEP and 100 in the TPWind, and the demarcation of who is inside and outside is then of great importance for the discourse on the ETPs. In one interview, one of the members asked me weather I asked him as an individual or as a representative for the firm. That there is a different seems to legitimize the narrative approach, rather the merely stringent sociological approach of perceiving individuals as stringently belonging to social groups. Also the members have changed along the way. One example is the CEO and Chief Geologist from Vattenfall**,** a Swedish utility company**,** who I interviewed as he has been a key member of ZEP since the beginning since 2005. Up to 2007 he was professor and geologist for GEUS, Geological

Survey of Denmark and Greenland, which is a research and advisory institute under the Danish Ministry. He then changed to Vattenfall, and today (2012) he recently send me his new coordinates, working for Gassnova - a Norwegian state enterprise for carbon capture and storage.

Because, the aim of this paper is not to unfold the discourse on the ETPs, but to investigate their operation; making the vis-à-vis competing alternative somewhat not that suitable for this purpose. First of all, the memberships follow the individuals and not the organizations. Secondly, it makes sense that the knowledge is a cognitive process; it is in the head of the individuals. The narrative approach of following the key players is therefore chosen as to perform investigations inside the organization and with interviews with individuals in key positions i.e. chairman or individuals pointed out as a central player.

Getting inside the platforms

ZEP: I started my case study on following this platform in May 2009 and have since then done an exclusive interview with member of the ZEP Advisory Council, CEO and Chief Geologist from Vattenfall, whom I had recently meet at my university in a workshop concerned with CCS. Furthermore, he recommended me to talk to ZEP secretariat asking for an invitation, and in the following GAs in 2009 and 2010, I join the GAs. In joining the GAs I had an opportunity talking to many stakeholders: from NGO's (WWF, former Greenpeace NGOs, and Bellona), sub-suppliers, CEO's from Siemens and geophysical companies from the global oil and gas industry, but as informal conversations. But, I also value the transport hours from Copenhagen to Brussel to continue our dialogue of his perception of ZEP and to validate my findings in mapping the stakeholder and barriers. In the GA 2011, he furthermore introduced me to chairman of the ZEP, a very busy individual during the GA – and so far impossible to reach.

TPWind: I started studying the platform in May 2009. I started with an interview with Head of Wind department at Risø DTU, Peter Hjuler Jensen on May 3rd, 2009 and later in October 19th, 2009. I did not get invited to the GAs in 2009 upon my request. Later I had the opportunity of meeting the project manager of TPWind from the European Wind Association being a speaker myself in an IEA expert group meeting in November 2009. The meeting was an opening conversation that gave me an invitation as observer to the next TPWind GAs plenum session in 2010. However, the status as an observer did not permission me to participate in the working group session. As the alternative was to spend 4 hours on my own during the program, I changed strategy and used the information of the program to schedule interviews with key players during my visit to Brussels. When first having the status as a TPWind observer, it made it easier to get people onboard for an interview – and when having the first interview scheduled, it was a lot easier to convince the next. In overall, getting inside in the platforms and getting the interviews booked was indeed a social process in creating trust and talking to the right people.

2.3.1. Data and methods

The narrative is constructed from interviews and key presentations, as well as from observations made while participating in the General Assemblies and selecting for interviews those who made themselves visible by making presentations at the platforms.

Exploratory interviews

Exploratory interviews were conducted in the early phase of the research to gain an understanding of the technical and organizational context in which the case objects, the ETPs in Wind and CCS, operate. The key stakeholders in Denmark were the first to be interviewed. Through an exploratory interview with the head of the wind department at Risoe DTU, Technical University of Denmark, who was noted as a key player, the UpWind project was identified as the partnership that first formed the TPWind platform. This interview was conducted in 2009. A key player in CCS is the CEO and Chief Geologist from Vattenfall, who gave a key presentation at the DTU workshop preceding the climate change meeting in Copenhagen in 2009. In addition to being a member of the Advisory Council, he was also one of the founding members of the ZEP in 2005, at which point he was working for GEUS, a Danish sector research institute with expertise in geological studies. These interviews were helpful in preparing for participation in the ETP General Assemblies.

Observation of ETPs in the General Assemblies (GA)

The GA gathers all the members of the specific platform, comprising approximately 200 members in the ZEP and 100 members in the TPWind. The GAs are usually held once a year, but in the initial stage of making the roadmaps, the GAs were held twice a year. As an observer, I recorded all of the barriers mentioned that were important to the sectors and who mentioned them to identify any conflicts that might lie in the barriers mentioned.

Semi-structured interviews

The interviews were conducted at a later stage using an interview guide for semi-structured interviews (King, 1994; 2004). The questionnaire was structured in accordance with the key outcomes from the extensive interviews with the Chief Geologist from Vattenfall. Each interview was projected to take 30-45 minutes. The stakeholders that were interviewed here all participated in the TPWind GA: the leading EU civil servant who was with the head of DG Energy and participated in both TPWind and ZEP and two leading researchers represented the industrial players at the forefront of wind power technology: Siemens Wind Power and Vestas. The interviewees were asked to name the most important barriers, if any, to bringing the sector forward. They were then asked to rank the barriers according to the likely degree of success of overcoming those barriers, and whether an issue was within the sector's capability to arrive at a solution. The interviewees were also asked about their self-interest in participating in the ETP.

Table 2.3.1. Overview of interviews

Exploratory:	
	Hjuler, P, Head of Wind Department, Risoe DTU. Technical University of Denmark, 19 October 2009.
	Christensen, N.P., Vattenfall, Chef Geologist and CEO. Copenhagen, 3 September 2009.
	Steenby, E. Professor and Director, EOR expert, DTU Chemical Engineering. Technical University of Denmark, 2 December 2010.
Semi-structured:	Christensen, L.C., Vestas, Vice President, Wind & Site Competence Centre. Technology R&D. Brussels, 3 March 2011.
	Gagliardi, F., TPWind Secretary General, EWEA Project Manager. Brussels, 3 March 2011.
	Kruse, H., Chairman of TPWind, Siemens Wind Power, Director of Government affairs. Brussels, 3 March 2011.
	Pedersen, E.L, Chairman of TPWind working group 1: wind conditions, Professor, Risoe DTU Wind department, Technical University of Denmark. Brussels, 3 March 2011.
	Sweeney, G., Chairman of ZEP, Executive Vice President, Future Fuels & CO2, Shell International Petroleum. Brussels, 4 October 2011.
	Tande, J.O, Chariman of TPWind working group 4: offshore wind, Director NOWITECH, Senior Research Scientist, SINTEF Energy Research. Brussels, 3 March 2011.
	Tostmann, S., Head of unit, Energy Technologies and Research Co-ordination, European Commission, Directorate-General for Energy and Transport. Brussels, 2 March 2011.

2.4. The emergence of the ETPs in energy

The EU Parliament, and particularly the European Council, plays a significant role in setting overall priorities, such as the overall budgets for the EU's framework programs, the grant types of the framework programs, and the overall priorities among major areas of science and technology.

In 2008, the European Union (EU) dependency rate for crude oil was 84.2 percent and 62.3 percent for natural gas, indicating that the current energy system is vulnerable to future grand societal challenges (Eurostat 2010). Energy systems around the world are facing grand societal challenges caused by climate change, scarce oil and gas resources and unstable energy supplies due to conflicts. These challenges are the emergent issue relevant to this paper. Europe needs a sustainable growth plan involving a transition to a low-carbon economy that leads to job creation and affordable energy prices. This type of plan was recently formulated by the European Commission, DG Energy following the track of the reviewed Lisbon strategy as a strategy to foster competitive, sustainable and secure energy sources. It is estimated that over the next decade, investments amounting to up to one trillion euro are needed to transform the current energy system in Europe, replace equipment and change resources (European Commission, 2011). This estimate brings to light a number of issues facing the EU: insufficient energy research budgets in the EU, structural weaknesses in technology innovation, and international competitors who are accelerating their efforts to challenge Europe's leading position in renewable energies (Peteves 2008; Norden 2009).

Today, the European Union consists of 27 member states. The largest expansion occurred in 2004, adding 10 new countries. Clearly, they did not all face the same problems, nor did they have the same innovation systems. An important analysis from the European Union has tried to distinguish common European problems from those that have to be dealt with at the national level. Furthermore, US and Japanese research policies, which use a differentiation approach rather than an imitation approach, could inspire Europe to select a few areas in which it has promising technological capabilities (Johansson et al., 2007).

The rationale basis for the ETPs can be traced back to the European Research Advisory Board report from 2004 that recommended the establishment of the ETPs with the knowledge that several platforms already existed. The main argument for establishing the ETPs was to ensure that European R&D responded to the economic changes and social requirements of Europe:

> *All too often in the past, European R&D, which could solve many of our economic, technical and social challenges, has failed to deliver. Issues related to regulation,*

finance, education, and markets created barriers in the innovation process (European Commission, 2004).

The original mandate for these platforms was on redirecting resources in a timely response to changes to meet the following goals: 1) deliver benefits to European citizens; 2) create competitiveness for European companies; and 3) reverse the trend in which investments in EU R&D produce fewer than expected benefits. The recommendations also considered who should participate in these platforms and emphasized that it should not only be R&D communities but also key players from industrial communities, companies, regulators, and consumer groups. As a result, the platforms should bring together critical players from the entire innovation process, thus ensuring both a vertical and horizontal coupling:

> *The Platform leaders - will be those engaged in bringing the technology successfully into the market. This emphasizes the companies commercializing the technology and other non-technical groups such as regulators and users. And it will be essential to get the right players – especially from industry* (European Commission, 2004).

To the question asked by the European Commission on why promising European R&D that could solve many of the economic, technical and social challenges fail to deliver (European Commission, 2004), the innovation system approach opens up to a rationality that much more sees problems of innovation as problem of a missing problems or missing components (stakeholder group) rather than markets that seems to fail advocating for tax and subsiding schemes alone. In my interview with Dr. Tostmann, Head of DG Energy of the European Commission (2010) he also said that the reasoning behind the roadmap processes severing as market information for the Strategic Energy Technology Plan was that '*The industries were a missing group in the Framework Programs.* The purposes of ETPs are therefore clearly an innovation policy instrument meant to engage industry stakeholders in the European Framework Programs. But, they have emerged into more than that. A small survey among the interviewees asking: "how they would characterize the ETP? The result is illustrated by a word cloud of valued statements in figure 2.4.

Figure 2.4. Statement cloud of the ETPs in wind and CCS

It values a strong voice of the industry focusing on the common vision, being a focal point, and delivering a European roadmap. Today, there are nine Energy Platforms, and seven of these are recognized as key technologies in the European Commission's Strategic Energy Technology Plan (SET-Plan), the mandate of which is to:

> *Achieve a certain policy goal or increase competitiveness in a certain sector* (Tostmann, European Commission, 2 March 2011).

The seven key technologies have delivered their roadmaps, which focus on R&D priorities, demonstration, and deployment, up to 2020. The Zero emissions platform (ZEP) was formed in October 2005 and the Wind Energy Platform (TPWind) were formed in September 2006. The two platforms, which this study is limited to, are centered on two key technologies: wind power and CO_2 capture and storage (CCS). Both technologies are considered technological solutions to the climate change challenges by the IPCC panel, the IEA and the EU Commission. Wind power is projected to play a significant role in achieving the EU target for 20 percent renewable energy in 2020. CCS is part of the transition solution towards a sustainable energy system, as both the IPCC and IEA projections forecast that renewable energy alone will not ensure an 80-90 percent reduction in the 1991 level of emissions by the year 2050. Both platforms are proving to be powerful players in adapting the EU Framework programs in research and technologies (FP6, FP7) to better suit the needs of industry and gathering knowledge via the participatory process about redirecting European R&D towards a low-carbon economy.

2.4.1. The story of the European Wind Technology Platform (TPWind)

TPWind was launched in 2006. The platform webpage says:

> *It is unique: the only body with sufficient representation or 'critical mass' of wind-specific knowledge and experience to be able to fully understand and map realistic and prioritized pathways for policy and technology R&D, taking into account the full range of sector needs* (TPWind, September 2010).

The members comprise stakeholders from wind industry-universities-government relations, R&D institutions, finance organizations and the wider power sector. New representatives from the oil and gas companies are participating as observers.

Much has happened in the wind industry within the last 20 years. Wind power started out with small entrepreneurs and rebel researchers with roots in the hippie environmental movement and a driving vision for making a better world. Originally, these researchers set out to experiment with nuclear power at Risoe, the Danish National Laboratory, when funding for nuclear power in the early 1970s was extremely limited. The researchers then started looking at alternative power sources and started by producing a wind atlas from the data collected from the wind mast placed in Roskilde, Denmark, to measure wind conditions in the case of a nuclear power release. In the intervening years, wind power has become a serious industry, as evidenced by the fact that at the TPWind general assembly on 3 March 2011, everybody was wearing a dark suit, white shirt and tie. The entrepreneurs have been replaced by managers and professionals in governmental affairs, and some of the pioneers now wear the uniform of those in a powerful industry.

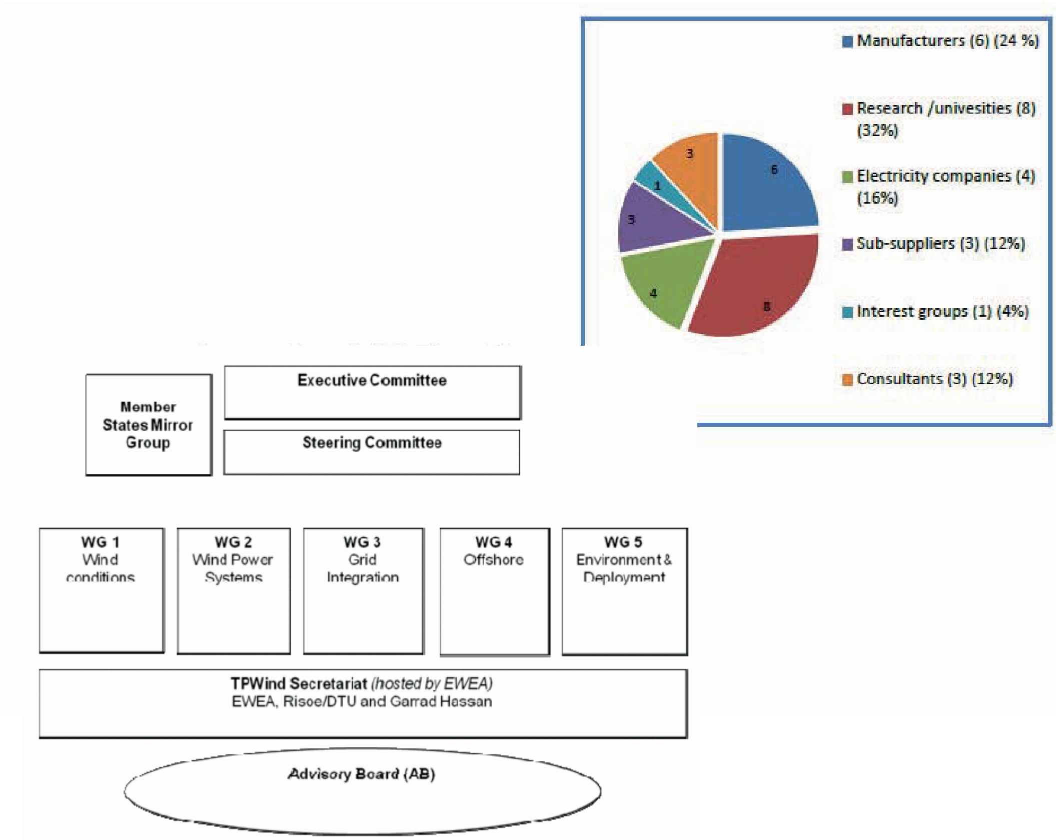
2.4.1.1. Problematizing: A Response to Major European Challenges?

At the beginning of the 1970s, research and breakthrough discoveries were the business of research institutions and small entrepreneurs; today, the wind firms have their own R&D departments. As the wind industry has become big business, it has also opened new markets for existing industries by placing demands on manufacturing, installation, maintenance, and electronic control systems. Recently, offshore wind farms have also been opening up new markets for oil and gas industries. In other words, the wind industry is setting the agenda for business opportunities in existing industries, and it is driving the generation of new knowledge in other industries. At the same time, development in the wind industry is dependent on technology transferred from other industrial sectors, such as aeronautics, shipping, steel and composites. Furthermore, globalization, including strong international competition from China and internationalization of R&D, is encroaching on the European wind industry, raising the issue of maintaining Europe's leading position as a wind power center, and the emergence of TPWind is the response to these major European challenges.

2.4.1.2. Enrollment and mobilization: key stakeholders of TPWind

The preparatory step for developing the collaboration network of the TPWind and pointing out the core members was the integrated EU project UPWind, which received 50 percent of its funds through the 6^{th} EU FP. The project included 43 partners from industry and research communities within Europe who agreed to the common vision: Wind energy should cover 12-14 percent of the EU's electricity consumption by 2020, with a total installed capacity of 180 GW. By 2030, this should increase to 300 GW of installed capacity. The stakeholders defined a Strategic Research Agenda with the expectation of implementation in the European Framework Program (FP7) and collaboration in Joint Undertakings between partners (Hjuler, Risoe DTU, 19 October 2009). The platform's stakeholders are responsible for mobilizing the significant human and financial resources necessary to fulfill this vision. From its beginning as a project partnership, the platform has now taken the form of an institutional body.

Figure 2.4.1.1. TPWIND structure and leadership, distributed by key stakeholders



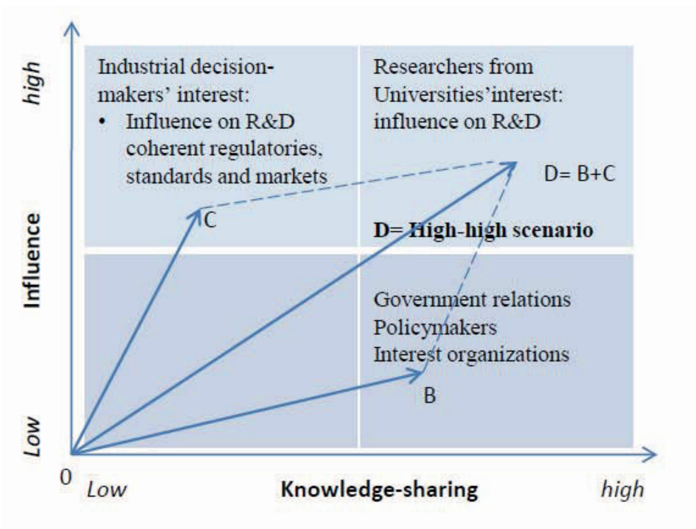
Source: the original organizational diagram from TPWind combined with the author's data on the members of the TPWind Steering Committee.

In TPWind, the Steering Committee represents the leadership of the platform. Figure 2.4.1.1 shows the structure of the organization under the TPWind leadership. It is made based on data collected from each member of the Steering Committee (which is in accordance with the sponsorship structure). TPWind's key stakeholders are divided into the categories that the members represent (read the diagram clock-wise). The figure shows multiple stakeholders from the business and science communities, but the membership is dominated by very competitive wind turbine manufacturers such as Vestas, Siemens Wind Power, Gemesa, GE Wind Energy, Iberdrola, and Alstom Ecotéchnia. These key stakeholders represent the leadership of the platform, which should be industry-driven. However, a dominating group in the leadership comprises representatives from research centers and universities.

2.4.1.3. Interest at stake and identified barriers

By gathering multiple stakeholders, different interests and expectations are also present and at stake. The roadmap process includes a negotiation phase: What are the most important barriers that are critical for success? Who has access to these? In TPWind, the manufacturers represent the largest group, which consists of multinational companies. The wind industry has developed rapidly in Denmark. Research centers and small entrepreneurs started the wind industry some 40 years ago, transforming their production from rural machines to wind turbines. As the wind turbine manufacturers grew larger, then technology advanced. Today, a wind turbine consists of approximately 1500 components. To continue this steady growth as the global targets for renewable energy creates a strong demand-pull, the manufacturers are developing in-house competencies and obtaining Intellectual Property Right (IPR) protection. Due to their size, the large manufacturers and suppliers are able to develop the necessary technology and components in-house. For a large manufacturer such as Vestas, the core IPR-protected technology is the wind turbine. However, why risk potentially leaking knowledge about what is part of the firm's core competitive advantage when R&D development can be performed in-house? Some of this knowledge could benefit from being shared with the strong research centers and universities, and the oil and gas companies through integrated projects, to support a knowledge center in Europe; therefore, collaboration and knowledge sharing are at stake in this sector.

Figure 2.4.1.2 TPWind interest matrix



The two-by-two matrix in figure.2.4.1.2 illustrates the knowledge-sharing conflict. The author inserted the power of conflict into a vector addition interpreted geometrically by the parallelogram law. The effect of the powers, and thus interest, would be a consensus leading to the high-high scenario of high influence on the roadmap combined with high knowledge-sharing.

Figure 2.4.1.3 Barriers and capabilities in the wind sector

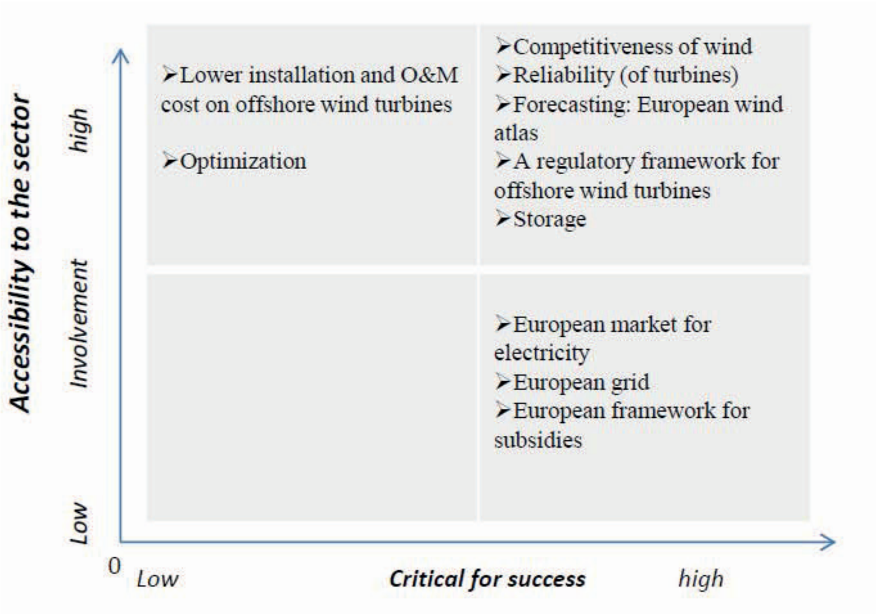


Figure 2.4.1.3 is a graphic representation of the ranking of the most important barriers identified in the interviews with the stakeholders. The interviewees were asked to name the most important future barriers for developing the European wind sector. The interviewees were then asked to rank the barriers on a scale from 1-5, 5 being highest. Off-shore wind turbines were ranked as 1-2, while a regulatory framework for off-shore turbines was ranked as 3. A European Grid and a joint market for distribution of electricity were ranked 5 (the highest, and in 5 out of 6 interviews, one ranked it 4). A European framework for subsidies was ranked 4. The results were plotted after the ranking in the interview and rated according to whether the key stakeholders would have the accessibility to the capability within the network.

The result strikingly shows that expectations for a co-evolution of the sector's development at a higher innovation level in Europe will only happen if new challenges for higher capacity are met.

The TP Wind roadmap is now the European Industrial Initiative (EII). However, the roadmap is perceived to be less important than the vision of the leading industrial stakeholders (Kruse, TPWind Chairman, Director government affairs, Siemens Wind Power, 3 March 2011; Christensen, Vice-President of Vestas' R&D Technologies, 3 March 2011, personal communication). The Vice-President from Vestas' R&D Technologies said:

> *The 2020 vision is now a driver for the sector* (Christensen, Vice-President of R&D Technologies, Vestas, 3 March 2011).

The TP Wind roadmap largely focuses on off-shore wind turbines; however, when asked to name and rank the barriers to developing wind technology further, ownership of the vision, as well as the vision itself, are perceived as difficult hurdles.

2.4.2. The story of the Zero emissions platform (ZEP, covering CCS technologies)

The Zero Emissions Fossil Fuel Power Plant Platform, which recently changed its name to Zero emissions platform or ZEP, deals with CO_2 Capture and Storage (CCS) technology. The platform was funded in 2005 on the initiative of the advisory committee to the European Committee on Clean Coal, which met in 2003.

2.4.2.1. Problematizing: A response to a major European challenge?

The focus of ZEP is on the deployment of CCS, and therefore, the vision is commercial: CCS is to be commercially viable before 2020. CCS is an emerging technology under active development; however, carbon capture technology originated in the gas industry (power stations), and the storage of carbon was first introduced in the oil industry. The main objective of ZEP is to reduce the cost of these techniques so that the technology can be commercially viable before 2020. This development of CCS can only be accomplished through large-scale demonstration plants, which means testing the CCS techniques in current coal-fired power plants in parallel with R&D studies. The other important issue is the public acceptance of the storage of CO_2 underground. This is called the NUMBY challenge (not under my backyard) (Christensen, N.P., Vattenfall, 2009). Since the establishment of ZEP, there has been visible political backing for CCS technologies. For example, in 2007, the European Council endorsed the Commission's intention to stimulate the establishment of up to 12 CCS demonstration projects by 2015. Such an initiative is the first of its kind in which the European Commission and industry joined together in an effort to demonstrate the feasibility of CCS in power generation and in lowering the current cost of electricity produced with CCS by the year 2020. Furthermore, the European Union committed itself in 2008 to reducing carbon dioxide emissions by 50 percent by 2050 and recognized the role of technologies enabling capture, transport and storage of CO_2 in achieving this goal (ccsnetwork, 2009).

According to Vattenfall's CEO, there is a huge amount of research in the R&D phase but little in the demonstration and deployment phase, which has led to a bottleneck in the innovative phase required for making CCS commercially viable before 2020. In his perspective, industry has an important role in the strategic debate between the EU and the key stakeholders because a vast technological domain, such as coal power plants, cannot be driven by R&D alone. Thus far, the issue in the debate leading up to the European roadmap on CCS has been centered on the following question: How many demonstration plants are necessary to prove that CCS can be commercially viable by 2020? The demonstration plants should be established in 2015. Currently, there are only a few demonstration plants, leading to an excess of work in the R&D phase and not enough advancement in the innovation phase. Although the research phase can include pilot tests, full-scale demonstrations of the technology are not feasible, Vattenfall's CEO explains. When we actually build a power plant with CCS or apply CCS to an existing power plant, there will be no data or experience to guide the process. There are no technological barriers, but there are market barriers such as the public acceptance and political barriers. For example, is this an acceptable technology? First, we need to consult the politicians to ascertain whether there is support for CCS at the commercial stage. How do we make a business model out of CCS and how should the development be financed? As the CEO of Vattenfall states

> *...if there is no roadmap of how to reach the vision in 2020 – it is rather impossible to mobilize resources and invest in this technology* (Christensen, N.P., Vattenfall, 3 September 2009)

2.4.2.2. Enrollment and mobilization: Key stakeholders in ZEP?

In ZEP it is the Advisory Council that is the management body. How the members of this decision making body was selected was not easy to find the answer to through interviewees. The research therefore in the case of ZEP included a social network analysis testing the learning from the TPWind that the members of the management body was formed from the Upwind project – an important EU project in a time with few EU sponsored wind projects.

Using the data of organizational partners in CCS projects dating back to the first time CCS was sponsored in an EU framework program in 1993. I then answered the question, if being central in the RD&D network prior to the forming of the Advisory council in ZEP would lead to a membership in the management body? Using SPSS software and a simple correlation, the answer is yes.

Table 2.4.2.1 The relation between RD&D networks and the ZEP

ZEP		Betweenness	Degree	Closeness
SC	Pearson Correlation	.395** (.000)	.486** (.000)	.477** (.000)

** Indicates that correlation is significant at the 0.01 level.

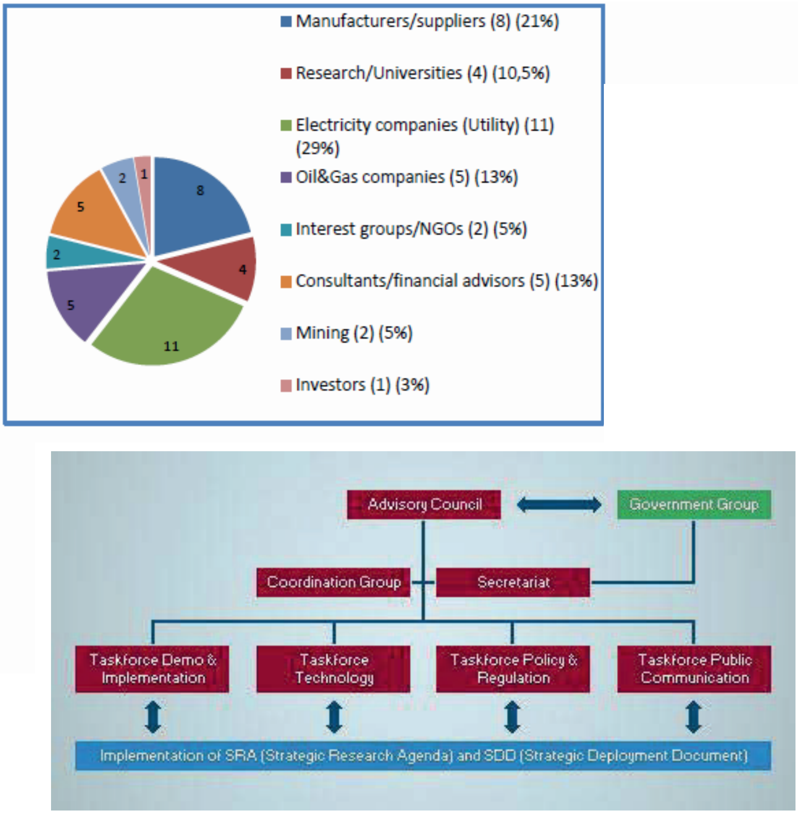
Illustrated in table 2.4.2.1 results are significant at the level 0.01, indicating that there is an overlap between decision making player at the platforms and those being important players in the RD&D projects.

The common vision was the first task and consensus among members took some time – *accordingly, three months* (Christensen, N.P., Vattenfall, 3 September 2009). Finalizing the strategic research agenda and the strategic deployment document at the end of 2006 was an eye-opener that required restructuring the taskforces. The main challenges were now the commercial viability, public acceptance and viability of CO_2 storage. The focus began to shift from development to implementation. The working groups, which were previously divided into different technologies, became a technology group, a demonstration group and an implementation group, and all of the working groups put out a call for qualified applicants. The Steering Committee then made a public call for applicants via its website, and invitations were issued through the network of the members. The co-ordination group selected the applicants. As applications arrived, the Policy and Regulation taskforce received an overrepresentation of researchers among the 46 applicants. Thus, the group decided instead to invite stakeholders from the business communities in the Eastern European countries to get a balanced taskforce.

The organizational structure of ZEP started as a network-like structure with five members composing an Advisory Council. It quickly developed into a governance structure with a Steering

Committee, and the activities were carried out by taskforces. The platform is supported by a secretariat that receives partial financial support from the European Commission under FP6/FP7; the rest of the financing comes from industrial sponsors, as the key stakeholders.

Figure 2.4.2.2. The organizational structure of ZEP and the leadership distribution of the stakeholders

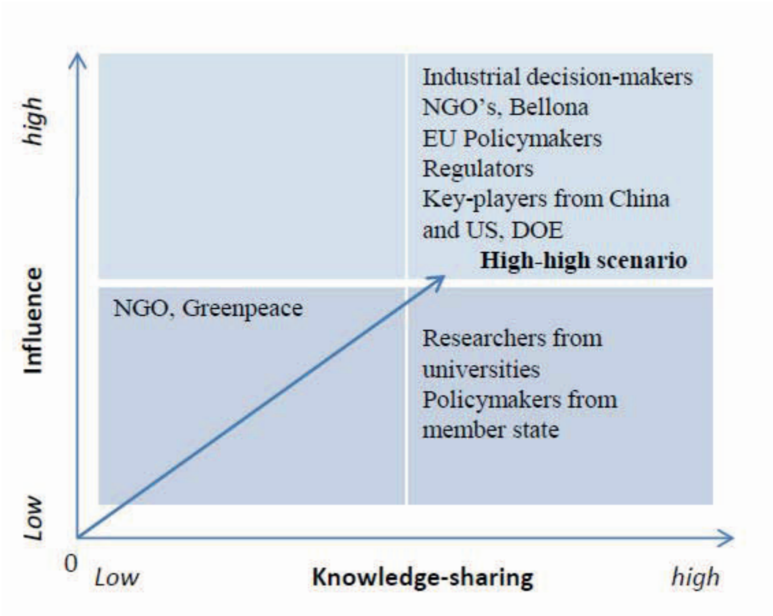


Source: the organizational diagram from ZEP (2010) combined with the author's data on members of the ZEP Advisory Council.

Figure 2.4.2.2 shows the structure of the ZEP, in which the Advisory Council forms the leadership of the platform, and the organizational types represented in the Advisory Council, which reflects the distribution of leadership among the stakeholders. According to the recommendations of the European Research Advisory Board's report from 2004, the key stakeholders should be industry-led. Reading the diagram clock-wise shows the distribution of the members by number of the Advisory council into different categories of firms. The main representatives are the electricity companies that own the utilities and the oil and gas industry. The figure illustrates the variety of stakeholders involved in the key decision-making process in the ZEP, ranging from the business community to the scientific community. The figure also shows the power balance in the platform, with the largest representation from industry. Within industry, the largest representation is from the utility companies, followed by the equipment suppliers and finally the representatives from the oil and gas industry.

2.4.2.3. Interest at stake and identified barriers

Figure 2.4.2.3. ZEP interest matrix



An Electricity company like Vattenfall, which sells electric power and heating, is interested in an open- knowledge process that includes all sub-suppliers because this may lower prices on components and contributes to a cheaper total solution than using only one sub-supplier. The equipment suppliers/ manufacturers, however, would like to close the innovation process to prevent leaking any of their knowledge on the components for commercially viable CCS power plants because such knowledge is superior technology and is protected by IPR. The oil and gas industries have a different approach because they already have the techniques, knowledge and technologies for CCS e.g. combustion techniques from the gas industry and transport and storage from the oil industry such as the techniques for enhanced oil recovery (EOR). Thus, CCS will provide new business opportunities that can utilize the techniques available to these industries. Currently, the consensus is by the researchers that public policy is lacking (Steenby, Leading EOR expert, 2010). This consensus may explain figure 2.4.2.3, where stakeholders come very close to the high-high scenario. Greenpeace was invited to the formation of the platform, but they have since changed their strategy from low carbon to zero carbon. The CEO of the NGO organization Bellona was appointed in 2007 as the vice-chairman of the ZEP Advisory Council. Their webpage states:

> *The appointment of the Bellona staff means the Oslo-based organisation's work will play a key role in forming the entire culture surrounding the development and implementation of emissions-free, climate friendly industry and technology across Europe, and eventually - via the platform's example - the world* (Bellona, 2007).

Figure 2.4.2.4 Barriers and capabilities in CO2 capture and storage

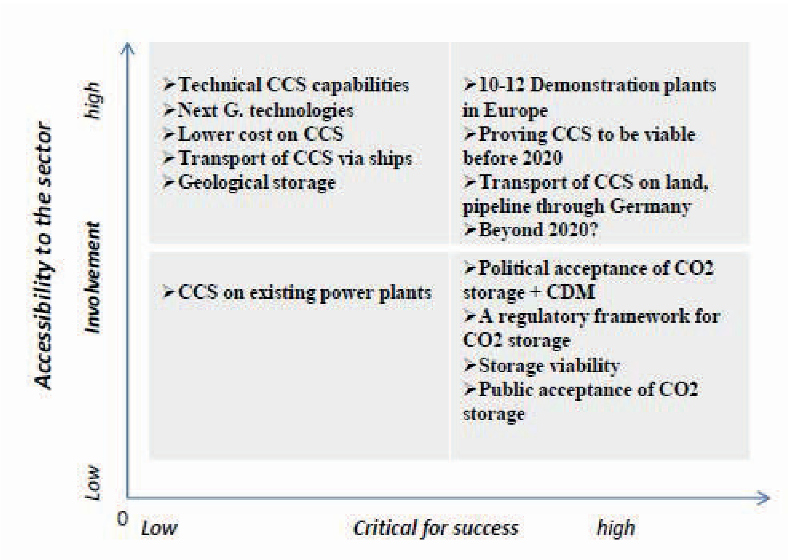


Figure 2.4.2.4 shows the barriers and capabilities critical to successful commercialization, ranked in relation to their accessibility within the sector and importance to success. The data and scores were extracted from interviews and presentations at the ZEP general assembly in 2009 and 2010.

CCS application in existing or new power plants is a high-risk investment because CCS has not been proven on a large scale, and the future of the technology is uncertain. It still lacks public as well as political acceptance at the national level. Until now, the EU incentives for a knowledge-sharing process have been the following:[3]

- Approximately 1 billion euros from the EU Recovery Plan distributed to remedy the financial crisis (that is 1/5 of the total budget for energy).[4]
- 150-300 million emission allowances – auctioning revenues from The New Entrants Reserve (NER) under the EU Emissions Trading Scheme (equals 1.8-3.7 billion euros at current carbon prices, but the EU Commission calculates they could be worth 6 billion euros).[5]
- Approximately 425 million euros from the seventh framework program (FP7).[6]

An efficient tool for dealing with multiple stakeholders and business interests has been a knowledge sharing plan, also referred to as a knowledge sharing document, which clearly presents what information can be shared and how. In the Technology taskforce, the discussion has been heavily focused on how to share knowledge. Because of the main discussion about what the projects are and who will finance them, the stakeholders estimated the cost of a highly efficient coal-fired power plant with applied CCS. They identified not only technical issues such as who has the best project? And also political issues:

> *You can have the CCS demonstration projects in the northern countries, but there also has to be one in Poland, as they would need to be spread geographically* (Christensen, N.P., Vattenfall, 2009).

When reflecting on the strategic process, the CEO from Vattenfall fears that there is a massive focus on getting the 10-12 demonstration projects but no focus on the next phases. After the demonstration plants, the real innovative step is to apply CCS in a full-scale power plant. Blindly following the Kyoto agreement and focusing on the 10-12 demonstration plants creates a vacuum. We have an artificial time horizon, whereas the USA has a more natural time horizon. When can we apply CCS in full scale?

[3] www.corporateeurope.org/system/files/files/article/Public_Money_ZEP.pdf

[4] http://www.europarl.europa.eu/sides/getDoc.do?language=EN&type=IM-PRESS&reference=20090505IPR55117

[5] http://www.euractiv.com/en/energy/eu-clears-extra-funds-carbon-storage-offshore-wind/article-188185

[6] http://cordis.europa.eu/fp7/energy/open-topics_en.html#carbon-capture-storage

2.5. Findings, interpretation and discussion

The observations made in this study revealed a clear line of command in the division of roles. Both the chairmen are highly respected industrial players in leading positions. The ZEP chairman is the leading executive vice-president of Royal Dutch Shell's CO_2 department, and the co-vice-chairman is from Bellona, a Norwegian NGO. The TPWind chairman is the Head of Government Affairs at Siemens Wind Power A/S. The findings were largely in accordance with the recommendations laid out by the European Research Advisory Board's 2004 report on the ETPs. The mobilization of allies seems strong; otherwise, the ETP would have to close (European Commission, 2004). Who speaks for whom? Statements gathered from interviews suggest that the ETPs are simply a strong voice for the industry. Assuming everyone understands this, it is a valuable communication tool that allows information to flow via more channels – this one from the markets.

Based on the processes in the two platforms, the author developed a model (figure 2.5.l) to illustrate the coordination processes between the multi-levels: micro, meso, and macro. The focus is on the process of generating a roadmap, and the creation of ownership and legitimacy of the vision and the roadmap. After the first prototype of the model was developed, it was tested in interviews with stakeholders from TPWind (both from industry and research) and the EU's leading civil servant from DG Energy, and then the model was refined.

Figure 2.5.1 Coordination model

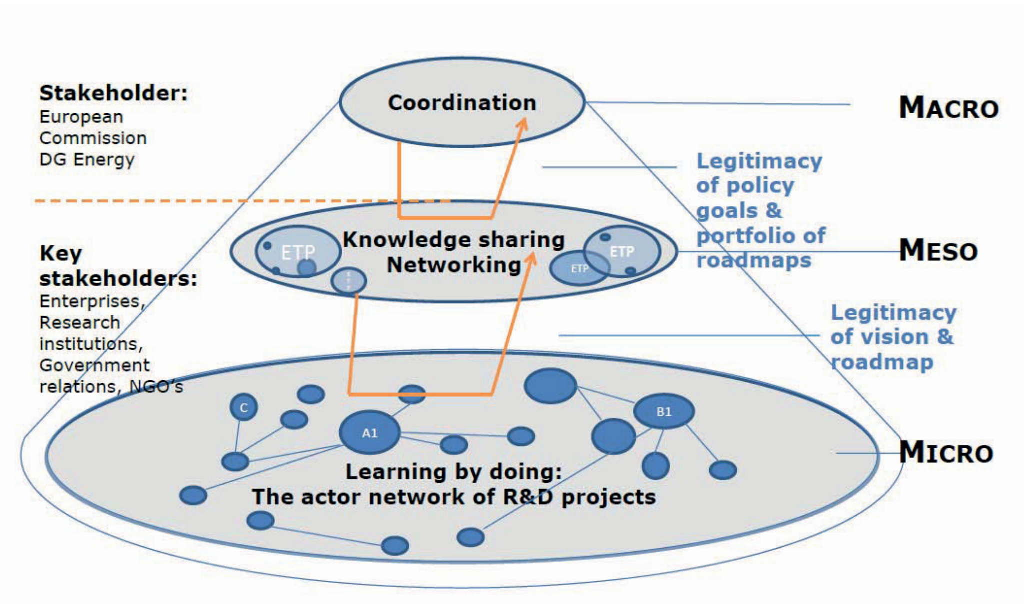


Figure 2.5.1 illustrates the bottom-up foresight process that creates ownership of visions and roadmapping processes:

1. Micro level is related to learning by doing in the R&D joint projects.
2. Meso level is related to face-to-face knowledge sharing, influence, information flows and networking in the platforms at General Assemblies and Steering Committee meetings to establish relations.
3. Macro level is related to coordination at the supra-national level.

The model illustrates the coordination process of the roadmaps. At the micro level, we have the actor network of R&D and the demonstrations that have been or are being carried out. The ETPs exist in the meso level, as there are seven platforms within the energy sector and all of these platforms deliver a roadmap. The legitimacy of the common vision, including the roadmap, in wind and CCS is established via negotiation processes, where the outcome and participants are visible (see exhibits I and II for the European wind roadmap and the CCS roadmap). The ETP actors only participate at the meso and micro levels.

At the macro level, the EU Commission's DG Research in energy and transport manage the process by integrating these roadmaps into a portfolio of energy technology roadmaps. This portfolio is then managed through common assessment frameworks such as the EU SET-Plan, ERA Strategy (Energy 2020) and the EU Framework Program for the amount of investment and support. After the negotiation process on estimates of investments needed at certain stages, the roadmap then serves as the European Industrial Initiative in Wind and in CSS.

The roadmaps serve as strategy and communication tools at many levels. The roadmaps serve as tools to communicate market information to the SET-plan's information system, the roadmaps serve as strategies for the European Industrial Initiatives, and they provide a transparent process that efficiently focuses only on the technology layers in the roadmap and a few milestones to align various funding schemes. The combination of the roadmapping tools and processes as well as the transparency in stakeholder participation makes this a visible process. Everyone has access to ZEP or TPWind via the Internet and can see who is participating in these ETPs.

> *These organizations are the ones that participate plus we invest this amount of money and for that they promised these deliveries within 2020. It becomes a visible process* (Tostmann, European Commission, 2 March 2011).

This study shows how the roadmaps function as a tool in the unification of European energy technology policies. At this stage, there are no policies on CCS at the member state level, although the roadmaps are pushing that agenda. The purpose of the roadmap processes from the perspective of the European Commission is to identify common European issues and challenges as well as opportunities to increase competitiveness. Clearly, the ETPs in wind and CCS are an example of how an actor constellation becomes a performing unit. The composition of the arguments regarding what has been solved and what challenges remain is interesting. For example, the barrier to public acceptance has been unquestionably overcome in the wind industry. In contrast, the main effort in the ZEP is to gain public and political acceptance of CCS, so it focuses less on technological barriers except from cost reduction and most importantly providing reliable estimates of CO_2 storage capacity as indicators on the viability of CO_2 storage.

The value of the strategic effort, from a policy perspective, is that it increases the effectiveness of public support and enhances the coordination of available funding schemes—both EU and national funding agencies can view the actions and priorities identified in the roadmaps. As a result, the added value of the roadmapping processes, from a business perspective, is that the ETPs and the collaborative model help clarify the long-term development trajectory of low-carbon technologies and contribute to creating security for investors.

The roadmap processes of the ETPs in wind and CCS show that the European Union is supporting a new mechanism that mobilize industry to deliver a high rate technical change through R&D investment. Hence, is this the right way forward in aligning policy goals and industrial innovation efforts?

Freeman (1996) argued that a new model of innovation would need to be evolved for a greening of technologies. This model would require a science and policy system that is highly responsive to social and economic changes. Teece and scholars (Pisano and Teece, 2007,Teece, 2007, Augier and Teece, 2009) have called such responsive capabilities within the firm for *dynamic capabilities*—in a political context that would be, sensing and seizing social and economic issues that need redirection of resources at the right time. This investigation illuminates the ETPs as a new governance mechanism, evolving along new, more dynamic capabilities, which are built-in via the more active and political role of the European Commission in directing changes in the existing science and technology systems.

2.6. Conclusions

This investigation used an organizational approach grounded in the original idea of the national innovation system (NIS), rather than a technological innovation systems approach (TIS), which would be too functionalistic and would not consider the dynamics of the contextual and time-dependent variables of why this is happening now and what type of actors are centrally positioned in the management of the specific ETPs in relation to their interests. The assumption for the investigation was that the processes of the ETPs can explain both a new trend in EU innovation governance and the technological trajectories that lead to beneficial technological paths.

Within the course of a few years, 36 industry-driven ETPs were established, accounting for a new corporate trend following the EU governance's shift to an innovation policy that is broader in scope and instrumentation than the previous science and technology policy had been. It was investigated how the strategic aspect of the ETPs in Energy has changed to introduce a new form of active governance that engages stakeholders, especially those in the industrial business community. The processes introduce roadmapping, a tool that since its introduction into corporate settings in the late 1970s is becoming more popular as a foresight process at the sector level. By introducing a new policy tool such as the ETP, the EU Commission demonstrated that the boundaries of strategy and priority-setting processes are changing from being constrained by a technocratic tradition relying on technological experts to expanding outside traditional institutions. The emergence of new policy tools as the ETPs reflects the fact that governments cannot be observed as the sole authority for making decisions; instead, government becomes the host of mechanisms involving non-governmental actors. Thus, policymakers themselves are the stakeholders. The strategic processes create a vision through highly consensual research agendas and indicate the powerful effect of engaging stakeholders that can mobilize changes in the form of existing technical capabilities and future investments in demand and supply technologies.

The ETPs are characterized by membership on a voluntary basis and highly consensual research agendas that create a shared middle- and long-term vision related to such emergent issues as shaping the current energy system and directing them towards a low-carbon economy. This is an institutional change that is co-evolving with the engagement of key stakeholders from industry, leading to an increase in the rate of technical change though R&D investment. The ETPs and the collaborative model between policymakers and stakeholders represent a somewhat new innovation policy tool. In this context, the policymakers and stakeholder create new roles in the alliances between industry, university and government, similar to a triple helix alliance (Etzkowitz and Leydesdorff, 2000; Johnson, 2008). However, the NIS perspective was chosen because it provides a broader perspective on the involvement of stakeholders and focuses on innovation as the engine for economic change (based on Schumpeter's writings), and grounded in evolutionary economic theory.

The emergence of this new policy tool, and thus a new institutional context, seems to follow the path from government to governance (Stoke, 1998; Ansell and Gash, 2008), which is also a paradigm shift from science and technology policy towards an innovation policy that is broader in its perspective because it focuses on the overall innovative performance of the economy (Lundvall and Borras, 2006; Lundvall, 2007). The broader scope of instruments means the inclusion of more players—in this case, the industrial business communities—because they are observed as powerful players in a knowledge economy. The structure of the information that flows from the ETPs to the framework programs and the SET-plan's information system is a technology roadmap framework, which has been recently considered in the literature as a foresight vehicle (Popper, 2008; Beeton et al., 2008). Therefore, this study was also an investigation into how the players in the European Technology Platforms work to create ownership of the visions as well as credibility as a source of information on technological trajectories. The structure of the relationship between stakeholders, vertically and horizontally, becomes the framework of a roadmap that serves as a medium for communication between many levels and thus as a carrier of a common vision.

The EU support of the ETPs are a change from a solely evidence-based policy to using bottom-up policies, which are based on expectations, uncertainties and visions, to mobilize human capital. It could be argued that the rationale has changed to an 'accomplishing-tasks rationale' that operates through a cooperative model. In the context of the two cases presented here, evidence is provided of a new knowledge model, which shows how the EU government, via an innovation policy tool, engages stakeholders from industry and research communities. Hence, the findings confirm that the ETPs are a valuable policy tool in forming EU innovation policy. In conclusion, the ETPs should be seen as innovative in the institutional mechanism of EU strategy and policymaking.

2.7. Policy implications and directions for further research

Formal alliances between members from science, industry R&D, and industrial production have proven very efficient in the development and deployment of technology. An R&D and demonstration alliance is becoming more essential as joint research is encouraged by the European Commission and implemented in the future framework programs and thus integrated into R&D projects. An R&D and demonstration alliance gives companies the opportunity to buy an option in technology research for a relatively low investment, which in time could have market potential. Moreover, previous efforts to make technology ready for market have been the task of industry alone; however, the current idea is that by bringing stakeholders together from the whole process of technology development from research to market. However, clear goals and incentives for science and industry to actively take part in *joint programming* activities should be set. It is envisaged that ETPs could be implemented in an international context in which a group of countries with a particular interest and capacity in relation to a strategic research topic join an R&D and demonstration program. Developing shared visions and mutually acknowledged strategic research agendas are important tasks for such alliances. Strong evidence for this is provided by the European Technology Platforms, which already exist at the European level. The platforms provide a meeting place for industrial companies and R&D communities to identify together, in a specific sector, the most important technological research and development advances necessary to achieve future goals in technology sectors.

However, it could be argued that the EU policy rationale has changed from simply setting targets to a corporate model involving the bargaining mechanism of visions and technological path creation. From an evolutionary economic aspect that draws on the terms variety and selection mechanism, it is critical to reflect upon the good intentions and practices and ask the question: Are the ETPs open to novel entrants? Are they able to create a bigger variety of technologies or are they simply reinforcing an existing path-dependency?

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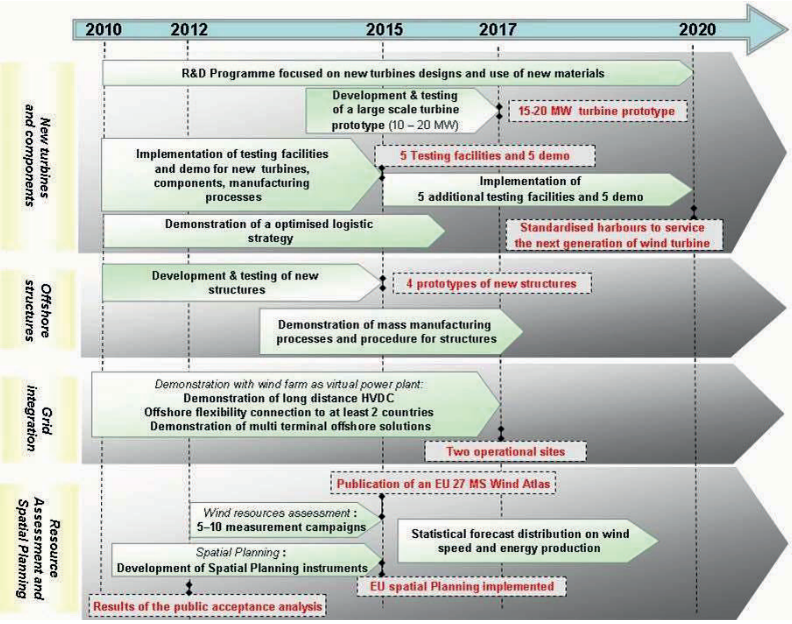
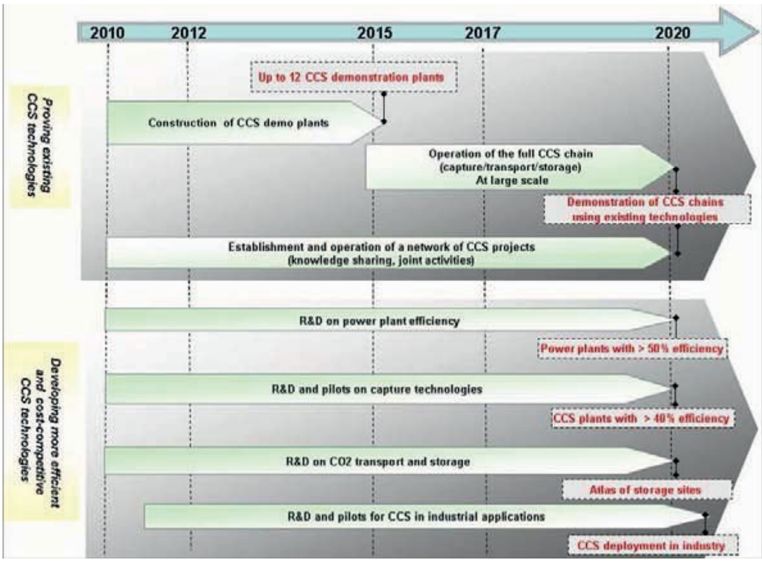
2.9. Exhibit I: European Wind roadmap – from the TPWind’

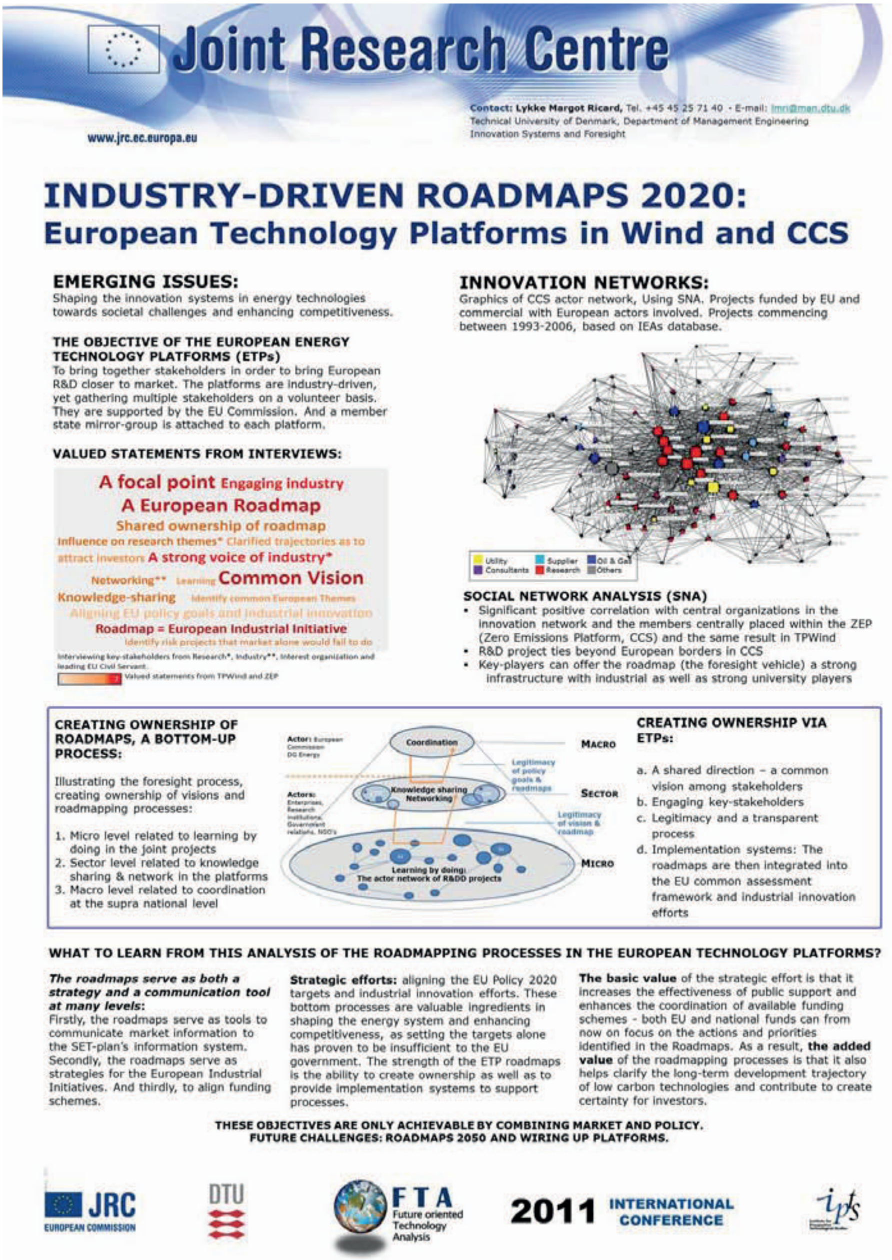


2.10. Exhibit II: European CCS roadmap – from ZEP



2.11. Appendix: Poster presented in the good practice closed policy workshop

Presented at the 4th International FTA conference, which was hosted by the European Commission, JRC, 13 -14 May 2011 in Seville, Spain.



2.12. Appendix: Interview guide

Semi-structured guide - questions to be adjusted along the interviews:

Basic information about the respondent. Please indicate the following
Full name:
Your Organization and Country:
Position and title:
Short description of your job:
Role in ETP or policy-making:
Generalist / or expert:

For the interviewer, please, tickle in the following table about the respondent:
☐ Expert
☐ Generalist
☐ With leadership responsibilities
☐ Without leadership responsibilities

QUESTION 1A: The most important issues about STI (Science Technology and Innovation) might be different in each country, how do you see the need of coordination of national STI policies in Europe?

- Any common European problems?
- Globally? (grand challenges)
- And have these changed since the establishment of the ETP?

QUESTION 1B:
What is happening now in Europe in this technological domain?
Wind technology is already a profitable business-model, so what are the challenges?

What are the barriers?
Technological barriers?
Market barriers?
Political barriers? (public acceptance?)
- **Ranking these on a scale from 1-5**
- Have barriers changed since the establishment of TPWIND?

QUESTION 2A: Why are the ETPs industry-driven?

QUESTION 2B: What are the most important global issues that Policy/Enterprise/R&D has to address/deal with?

- In TPWIND rank the importance of the R, D, D, D and U (scale of 1-5)
- In your opinion how would you prioritized them at current stage?

QUESTION 3: In your opinion, what are the values of the innovation discourse in the ETPs in relation to:

- The faster pace in the internationalization of R&D (escape from European R&D?)
- The role of the Multinational Enterprises
- Innovation networks (global/local)
- Lead markets

QUESTION 4A: Why are you participating in this ETP? /
What is the need of a European wind roadmap?

- How to finance the development?
- Roadmap of how to reach the vision?
- mobilize resources and invest in the technology

QESTION 4B: How do you see the ETP as an 'Open Method of Coordination'? (examples are welcome from TPWind)

- Challenges?
- Knowledge sharing – core assets versus complementary assets
- The two dimensions: 1. coordination and 2. learning
- On a scale on 1-5, where do you see learning in the ETP and where do you see coordination on that scale?
- In your opinion why is it roadmapping that have been the preferred tool to support the strategic coordination?
- Strengths of the vision? Value (1-5)

Reflect on model **– see figure 2.5.1 in article (presented a prototype to that model).**

QUESTION 5: Value propositions:
What is in your opinion the overall value of the ETPs?

- **What is the basic value of the coordination process?**
- **What is then the added value?**
- **Why is this not achievable by market alone (or policy)?**
- **What happens after the transformation to a JTI?**

3. Chapter three: European Technology Platforms in wind and CCS: new innovation policy tools and corporate strategizing

This chapter builds on an paper presented and published as conference proceedings in the 14th International Schumpeter Society Conference, 2-5 July, 2012, Brisbane which was hosted by the University of Queensland.. The paper is invited for submission for publication in a special issue in Journal of Evolutionary Economics with a deadline for submission before 16 October 2012.

Author
Lykke Margot Ricard, Technical University of Denmark, Department of Management Engineering.

Abstract

This paper is concerned with policy and the role of new experimental innovation policy tools for structuring change and coordination with industrial efforts in moving towards a low carbon economy. The paper presents an evolutionary economic perspective on the industry-led European Technology Platforms (ETPs) in wind power and in carbon capture and storage technologies, and the role they play in the creation of a new European strategic energy technology plan. The paper is positioned within the discussion of innovation system and system thinking to work as an antidote to the neoclassical economic idea of market failure, which has been a dominating rationale for science and technology policy. The proclaimed assumption deduced from theory is that in innovation systems, the connectivity between key-actors evolves in relation to a certain problem (Metcalfe et al., 2005). This paper's case study verifies this thesis; furthermore, it examines how firms in the modern European economy, on the collective level, work from within the political system to create new institutional structures in the economy. At the same time, they shape and unfold technological trajectories around specific major societal problems in important ways. Transferring the theoretical concept of system thinking on industry-led ETPs is much related to the important role of connectivity and entrepreneurship, in the sense that I examine how future technological trajectories towards low carbon economy are being shaped in interaction between EU policymakers and the incumbent firms that are acting as entrepreneurs. This thinking is thus related to Schumpeter's Mark II innovation; it is however a step towards entrepreneurial activities at the collective level within an economic system and knowledge-specialized society, where connectivity and network-like relations

play an important role in innovation, as opposed to arm-length anonymous interactions as presumed in neoclassical thinking.

Key Words:
Evolutionary economics, innovation systems, innovation policy, structural change, social network analysis, European Technology Platforms, wind energy, carbon capture and storage technologies

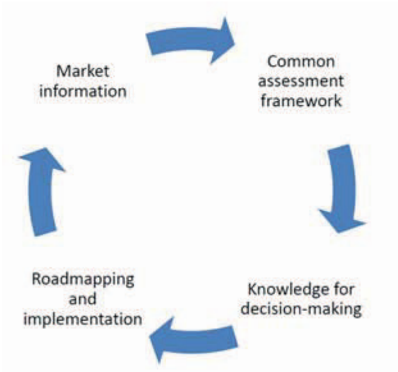
3.1. Introduction

The emerging issue involved in this study is the shaping of the innovation systems in energy technologies to address societal challenges such as securing energy supply, mitigating climate change via reducing CO_2 emissions, and at the same time enhancing European competitiveness as declared in the Lisbon strategy in 2000 and in the revised version in 2005.

The European technology platforms (ETPs) are industrially driven, yet a focal point for EU policy makers, industry, and academia. They are not a technology platform in the physical sense, but more a knowledge sharing and strategic platform. They are a meeting place for industrial companies meeting with R&D communities in order to identify the most important technological research and development necessary for enabling key technologies to solve societal challenges. These are formulated in the Strategic Research Agenda (SRA). On the basis on the SRA, the ETPs are to give advice on implementation of the strategies – that is, to advise on the possibilities for the newly developed or improved technologies to penetrate the market – which are formulated in the Strategic Deployment Document (SDD). These two documents are of great importance to the future RD&D as they are important input in the content and priority-setting of the EU Commission's work with the research programs and call for projects. Furthermore, the ETPs are catalysts in mobilizing substantial public and private funding sources for their subsequent implementation.

The European technology platforms have emerged quickly since their formal mandate in 2004, accounting for 36 platforms. In 2008, wind and CCS officially became a part of the European Strategic Energy Technology Plan (the SET-Plan). This was a turning point in that ETPs in key energy technologies come to play a key role in this information system. The rationality was clear as it was important to get the key stakeholders onboard that refer to the firms capable of commercializing new technologies (Tostmann, Head of Unit, DG Energy, European Commission, personal communication, 2010). These ETPs were to deliver a 2020 roadmap clarifying the long-term development in the trajectory of low carbon technologies, contribute to the coordination of available funding schemes, and create certainty for investors (Gagliardi, EWEA, TPWind project manager, personal communication, 2010). Furthermore, they were to form a joint technology initiative or a flagship program, today called European Industrial Initiatives. This information feeds into the SET-Plan as market information.

Figure 3.1. The SET-plan's information system



Source: www.setplan.be

First of all, when investigating these platforms, we must ask the question: Why are these technologies important? Sectors with high economic growth are important. Obviously, they are getting a larger slice of the cake, and the explanation for their growth is worth investigating. The technologies are important, since they point the way to solving some of the societal challenges that the world is facing due to the fossil fuel energy system. Obviously, the European problems are not only environmental; they are also related to energy supply; and to the creation of jobs. Wind energy and carbon capture and storage technology in fossil fuel power plants were pointed out by the European Commission in 2008 as key technologies, as they entail a high potential for increasing European competitiveness (Tostmann, European Commission, personal communication, 2010).

Wind power is a maturing renewable energy technology that possesses a high growth factor, possible of creating new jobs. Yet, it is still a niche industry and still relies on being subsidized. The oil and gas industry, on the other hand, is an old industry and very powerful, as it has a history of strong lobbyism. It is also a sector with high economic growth, although fossil fuel appears to be the villain in the public debate on climate change issues. However, CCS was recognized as a transition technology by the Intergovernmental Panel on Climate Change in their fourth assessment report of 2007. In 2008, the European Union committed itself to reduce carbon dioxide emissions by fifty percent by the year 2050, and officially recognized the role of technologies enabling CCC.

Today, there are already planned ten CCS demonstration plants in Europe. The latest development, however, is to apply CCS mainly in gas power plants.

Industries are therefore never status quo, as they are influenced by many factors including their own adaptation, and specifically those firms in highly regulated sectors by being proactive in pre-political strategy-phases shaping public opinion (Hillmann and Hitt, 1999). But it is a vice-versa relationship, as policy makers also attempt to build relationships across issues and time. In recent years, the economy has become more vulnerable to fluctuating oil prices, and the high oil prices have made it more feasible to explore alternatives. Coal is still one of the cheapest energy sources and so is gas – the problem with gas is that it transports via pipelines across countries, making transport vulnerable, also to conflicts and negotiation processes. Then, there is also the issue of nuclear power plants: In Denmark, nuclear power was removed from policy programs as a possible source of energy in the early 1980s after a hectic public debate in the 1970s. The technology only reached the stage of test facilities. The earthquake in Japan in 2011, which caused a tsunami that was much larger than the Fukushima nuclear power plant was designed for, turned out to affect policy all the way to Germany. Here, Angela Merkel decided that Germany's policy from then on was to close down the old nuclear power plants and instead increase the strategy of wind power plants. In Denmark, the anti-nuclear decision in the 1970s was a push for more wind power. Today, approximately twenty percent of wind power is integrated in the grid. Obviously, the Danish wind adventure did not happen overnight, as it is based on almost forty years as an emerging technology. There is therefore no doubt that the possibilities for new technologies to meet societal challenges and increase competitiveness also create political pressure that results in new incentives to develop the technologies and diffuse them at a much faster pace – beyond business as usual.

3.2. Theoretical framework

Inspiration comes from the following sources:

"The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers, goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates" (Schumpeter, 1942:82).

"I like to think of the economy as a system. As the creative destruction works 'from within' as Schumpeter called it, the system creates its own future by challenging its path" (Metcalfe, 2011)

"Much of the utilitarian tradition, including classical and neoclassical economics, assumes rational, self-interested behavior affected minimally by social relations, thus invoking an idealized state not far from that of these thought experiments. At the other extreme lies what I call the argument of 'embeddedness': the argument that the behavior and institutions to be analyzed are so constrained by ongoing social relations that to construe them as independent is a grievous misunderstanding" (Granovetter, 1984: 481-482).

This paper is concerned with the ETPs as new important innovation policy for structuring change towards a low carbon economy. The paper presents an evolutionary economic perspective on the industry-led ETPs in wind power and in CCS, and the role they play in the creation of a new European energy technology policy. The paper is positioned within the discussion of innovation system and system thinking. Metcalfe (1994) presents Freeman and Lundvall's concept of the (national) innovation system (NIS) as an antidote to the concept of market failure that has been the dominating rationality for science and technology policy. The innovation system idea focuses on connections within boundaries and includes the role of universities. It suggests seeing problems within innovation as problems of system failures (Doggson et al., 2011). This is a new perspective from benchmarking innovation systems to transformation of innovation systems, where the essence of the innovation system concept is co-evolution of organizations, knowledge and institutions (Freeman, 1995; Lundvall et al., 2002; Lundvall et al., 2002; Lundvall, 2007; Freeman and Soete, 2009).

The historical approach to studying the two ETPs as they evolve over time is also inspired by the writing of Loasby (2001:393). As he phrases it: "Time matters because knowledge changes." This is also why connections matter. The methods, processes and social interactions in the ETPs are representations of the structural change and coordination that is changing the patterns of macro- and micro-level economic behavior. In this analysis, it is the ETPs that are the central focus of the analysis, as agents in the relation between changes in the micro- and macro-processes (Dofper et al., 2004). Indeed, this research builds on a multidisciplinary framework as it is inspired by many great ideas, but grounded in the Schumpeterian idea of economic change that revolves around innovation.

The rationale behind the establishment of the design of the ETPs is that of system failure. The industry was simply a missing actor group in the incoming application in the EU framework programs (Tostmann, European Commission, personal communication, 2010). The hypothesis is that the policy rationale behind the ETPs builds on the idea of innovation systems as open and dynamic systems, not national, regional or technological. To test this idea in practice, in the ETPs, the connectivity should evolve around solving certain problems. Empirically, this could be tested, if there are changes in the platforms since the origin of ZEP in 2005 and TPWind in 2006 up to now. In both platforms, there has been organizational change in the working groups. It is therefore necessary to investigate and analyze this change and then explore the changes in network structure. Supporting the social network analysis (SNA), key documents and interviews are used to seek to understand the rationale base and investigate whether there is a relationship between connectivity and the identified barriers in these two systems. The paper then takes up the discussion of the innovation system concept and whether the ETPs bring anything new to the debate. It furthermore positions the ETPs within a discussion of policy based on system thinking versus a market-failure rationality with implication that each paradigm opens up to different policy instruments (Metcalfe, 1994). System thinking can be seen as an antidote to the rationality of science and technology policy that has been based on market failure. The system perspective opens up to a rationality that sees problems of innovation as problems of missing actors or missing problems, rather than as markets that seem to fail. Both ideas are considered to be rationales behind policy interventions.

3.2.1. Innovation systems and evolution

To understand the innovations system approach, it is important to understand the underlying economic thoughts, which are evolutionary economics and stand in opposition to neoclassic economic theories. Neoclassic growth theory has been constrained by theories based on mechanical concepts of equilibrium (Nelson, 1995) and is also blind to the important role of the institutional frameworks that set the rules for the economy. While neoclassical economic theory assumes full information and independent utility functions, evolutionary economics builds on uncertainties, expectation, and also some sort of 'systematic selection mechanism' that opens up for a broader understanding of what is actually happening at the micro level, and not simply policy leanings based on aggregate models (Georghiou and Metcalfe, 1998). The evolutionary perspective leads to an understanding that sees the variations among firms and technologies – i.e. why some firms actively participate in emerging technologies such as carbon capture and storage, even though there are major uncertainties about whether it will ever reach a commercial stage.

Naturally, the ETPs are not addressing national system of innovation, nor are they necessarily addressing technological systems. Scholars of technological systems developed in the 1990s have said that it is the institutional framework that defines a technological system (Carlsson and Stankiewitz, 1991). But then, how can the ETPs be technological systems? The reasoning must necessarily be that the ETPs are more than technological systems, perhaps evolving from networks, but indeed institutionalized. The important works of (Malerba et al., 1997,Malerba, 2002,Carlsson and Stankiewicz, 1991) address the varieties in institutional frameworks according to the technology in play and maturity stage. Sectoral systems of innovation could be another choice. The various concepts all address important issues related to system thinking, and it is obvious that a theory needs to combine work at different levels of aggregation.

The theoretical point of departure, and perhaps also an important assumption deduced from this theoretical discussion, is that an innovation system needs to be seen as an open system concept (Lundvall, 2007). The specificity may be technological, but the innovation system idea also implies some sort of systemic innovation, meaning that changes in one part of the system also necessarily lead to change in other parts of the system (Langlois and Robertson, 1995). The ETPs are new policy tools, and they are guided by innovation policy referring to focusing on the overall innovative performance of the economy as defined in (Lundvall and Borras, 2006). Currently, the ETPs in energy are highly influencing the EU technology policy and strategies by delivering 2020 roadmaps as part of the European Strategic Energy Technology Plan's information system. The ETPs are capable of changing the institutional framework, which scholars of technological systems have said is what defines the technological systems, and therefore there must be more empirical study of them to contribute to theory. In some sense, they are European institutions, but innovation is not captured at the supra-national level. Innovation goes beyond European borders and is much more than technological development related to the supply side. By introducing new mechanisms to the institutional frameworks of the economy, it changes the rules of the game. This is why, in the study of the ETPs, I choose to focus on the idea behind innovation systems as the idea of system thinking as opposed to the idea of market failure. This perspective is based on neo-institutionalism, where time matters in relation to knowledge. It is the historical school of neo-institutionalism that sees ideas as embedded in social action, where ideas are worldviews of certain individuals or groups. These ideas are linked to cognitive frameworks and are also the basis for policy frameworks. When the ideas change, it makes sense that the policies based on these conceptual ideas also undergo change (Biegelbauer and Borras, 2003). The proclaimed assumption of the analytical framing in this paper – using the innovation system approach as an open system concept evolving around connectivity – is therefore that the connectivity between key actors revolves around a certain problem (Metcalfe et al., 2005), and as time goes by, interactions are established and even dissolved (Lundvall, 2007). This can be formulated as the first research question:

RQ: If there is a change in the problem, does connectivity changes in a way that makes sense in solving the problem?

3.2.2. Social networks

The idea of embeddedness was first articulated by Karl Polanyi in his book *The Great Transformation* from 1944. The idea is that economic relations among individuals and organizations are embedded in actual social networks and do not exist in abstract idealized markets. The idea is also related to moral economy and to Marxist thought (Granovetter, 1985). "The problem of embeddedness" was written by Granovetter in 1985; its theory stresses the importance of relations, and is in contrast to reductionist theory that focuses on individuals alone. Additionally, it also contrasts to explanations using variables, where structure seems to be the connecting variables rather than actual social entities (Granovetter, 1994). Social network analysis (SNA) is a structural analysis that is "widely used in the social and behavioral sciences, as well as in economics, market and industrial engineering" (Wasserman and Faust, 1994). It is the mapping and measuring of flows and connectivity between individuals, groups, firms or even collaborative projects.

The nodes are the organizations, and the ties comprise the relationship or knowledge flow between the nodes. SNA is chosen in this study as it provides both a visual and mathematical analysis of relationships between organizations that form a network. Creating a network based on co-membership is accomplished through creating an affiliation network, which is a two-node network. Let me first define what I mean by nodes. First, I have a set of actors that consist of a number of organizations (names of organizations N= $\{n_1, n_2, \ldots.n_g\}$), as the first of the two nodes. The second node is the events; in this case, the Steering Committee (SC) in TPWind and the working groups (WGs). In ZEP. it is the Advisory Council (AC) and the working groups, which I denote as WGs = $\{wg_1, wg_2, \ldots wg_h\}$. In general, this means that an actor is affiliated with an event: if the actor belongs to the event – in this case, if an organization is a member of working groups, the following rule applies:

$$Oij = \begin{cases} 1 \text{ if the organization i is affiliated with the WGj;} \\ \qquad 0 \text{ if otherwise} \end{cases}$$

It can then be said that an affiliation network is *"…information about subsets of actors who participate in the same social activities"* (Wasserman and Faust, 1994: 294). Thus, I create a simple matrix using Excel, with a row for each of the organizations and a column for each of the working groups, WGs, following dichotomous coding to create the affiliated networks. The design of the matrix (illustrated in table 3.2.2.) using the organizational categories forming the membership of the platforms could then be developed using Ucinet for analysis (Borgatti et al., 2002).

Table 3.2.2. The data matrix

(Steering Committee (SC), (W1,W2, W3, W4, W5….)

Name on Organization	SC	WG1	WG2	WG3….
E.ON	0	0	1	1
Statoil	0	1	1	0
Vattenfall	1	0	1	1

Analytically, the duality means that I can study the ties between organizations or between R&D projects. As I am interested in the relation between organizations, I choose to create a one-node network based on the names of the organizations, the rows. In a one-node network, two organizations are linked as pairs, if they are both affiliated with the same sub-group. I can then refer to the relationship between the organizations as co-attendance, co-membership, and collaboration.

With the network consisting of the ties between actors, I can then analyze it as if it were a one-node network, thus finding the 'most important organizations' based on different types of centrality.

The following brief definitions of centrality measures are modified from Wasserman and Faust (1994) and orgnet.com/sna (accessed, March 2012):

Degree: Actor centrality is defined as the most active actor, the one with the most ties to other actors in the network. This is the 'busy bee', one of the most active nodes in the network, a 'connector' or a 'hub' and perhaps also one of the most visible nodes in the network.

Betweenness: These are the 'brokers' in the network. They are located in between important actors and play a powerful role in the network; they are the ones controlling the outcomes in the network.

They are ‘decision makers’ and are also seen as the ‘high influencers’, as they have the best location in the network.

Closeness: Actor closeness is the sum of geodesic distances and defined by the measurement of connections, which indicate how far an actor can go in the network, accessing all the nodes in the network by ‘the shortest path’. Actors with a high degree of closeness are in a good position to know everything that goes on in the network and also in a good position to diffuse or spread news.

Without the ‘connectors’, the ‘brokers’ of ‘the high influencers’, there would be no network; if these important nodes were removed, the connectivity would be dissolved, resulting in a collapse of the network.

Core/Periphery structure

One aspect to keep in mind when focusing on networks dealing with technological developments is the idea of novelty, or of networks being open to newcomers. Homogeneous individuals tend to cluster, said Granovetter (1973); and after a period, they tend to think much alike, making innovation slower (Burt, 1992). In contrast, Power (1990) points at the positive proposition of homogeneous groups as the higher level of trust makes it easier to sustain the network-like relations. Though there might be clusters in a network, Burt (1992) says that between the clusters, the individuals are heterogeneous, and when somebody mediates between them, innovation seems to increase. Deducing from these points, the number of newcomers – whether in the network or in organizations moving between clusters – would give some indication of the dynamics in the network. This can then be formulated as a sub-question to the first research questions:

Sub-RQ: Are there any newcomers in the platforms membership (Are they dynamic?) or are they more likely to become clubs and therefore less likely to be innovative?

Large networks feature a core and periphery structure, meaning that these network possibly “entail a dense, cohesive core and a sparse, unconnected periphery” (Borgatti and Everett, 1999:375). The core in the network may be seen as a dominating central cluster, and compared to its core, the periphery has fewer connections. The core is then defined by those actors that have a high frequency of interaction and often participate in the same events. Therefore, if this structure applies, platform members can then be placed into two groups: either the tightly interconnected group at core, or the relatively disconnected group on the periphery.

The analysis using the Ucinet 6 software (Borgatti et al., 2002) is based on a genetic algorithm using equations 2 and 4 from Borgatti and Everett (1999); it simultaneously fits a core/periphery model to the data network, and identifies which actors belong in the core and which belong in the periphery. The fit is a correlation based on the density measurement, which is calculated as the numbers of ties existing divided by the maximum number of ties possible in the network. In the core/periphery structure, the "fit function is the density of the core block interactions" (Borgatti and Everett, 1999).

3.2. Methodology and data

In search of a practical approach, social network analysis (SNA) provides both an analytical and visual approach to mapping relations and capturing the informal structure.

I have gathered the pieces that form the data on each individual, their organizations and the organizational structure of the two platforms, linked to the exact time of co-membership. Data was gathered through the platforms' websites, desk research of the minutes and key documents, and also mail correspondence with chairman of taskforces, working groups and the secretariat to complete my data-set on members of the platform at the given time. I then transformed the data from the individual level to the firm level, providing the name of organization. The data was then used to study connectivity over time. Since I was aware that even though the analysis is based on historical data, it cannot stand alone, I combined the findings of the SNA with reflections from my own observations while participating in five general assemblies – two in TPWind (in 2010 and 2011) and three in ZEP (in 2009, 2010 and 2011) and information from interviewing the two chairman of the two platforms investigated. The analysis therefore includes the role of stakeholders over time in the technology platform, combined with knowledge of the identified problems and barriers in the course of the learning and knowledge processes that can be tracked in the key documents – such as the platform's early strategic research agendas and the roadmaps 2020 published later.

Having two complete sets of data for two periods of time, which are situated between changes in the working groups, makes it possible to perform an analysis over time and investigate if the change in working groups due to the change in the problem would also lead to a change in connectivity.

To tell us something about how they are connected and how the relations have changed, two analyses are supportive:

- ✓ Changes in leadership, performing a centrality analysis calculating multiple centrality measures such as degree and betweenness
- ✓ A cluster analysis, performing a core/periphery partition to compare the two periods and to detect newcomers in total, but also how these are distributed: newcomers in core or periphery, and organizations moving from periphery to core or from core to periphery.

In the core/periphery analysis, the number of iterations was set to 50, and the size of population in the four network analyses was set accordingly to the number of organizations in the network – between 88 and 124 organizations. This analysis allowed detecting how the networks change over time in the structure of the two platforms, with focus on the organizations.

3.3. TPWind network analysis over a four-year time period

TPWind was launched in 2006 with broad policy backing; however, it was the project UpWind funded by the 6th EU Framework program that brought the network together to establish the platform (Hjuler, DTU Wind, Coordinator of UpWind, personal communication, 2009). This project was the preliminary step for developing the network that should lead TPWind. The project included 43 partners from industry and research communities within Europe. Behind the UpWind application were European Wind Associations (EWEA) and the European Academy of Wind Energy (EAWE), and these organizations still play a strong supporting role today. The main industrial actors in the TPWind project include a large wind turbine manufacturer, and also a small firm with expertise in aerodynamics. The vision that wind energy will cover 12 to 14 percent of EU's electricity consumption by 2020, with a total installed capacity of 180 GW, which is seen as the main driver. By 2030, the vision is to increase the installed capacity to 300 GW. TPWind has declared that it will also assess the overall funding available to carry out this work, from public and private sources.

In November 2007, TPWind decided to focus much more on the barriers to including more wind power in the grid and expanding towards offshore wind power plants. This was a result of a common visioning and roadmapping solution, which recognized the high potential of utilizing the wind power resource at sea. As size of the turbines matters at sea, the solution was also the answer to an innovation trend to make wind turbines, rotors and blades larger and thus more effective, which would be an outcome of the UpWind project. Bigger turbines would of course demand greater geographical safety distances to their neighbors' backyards. Thus, moving offshore would avoid one of the strongest public challenges, the not-in-my-backyard (NUMBY) challenge.

At that time, TPWind's organizational body consisted of an executive committee, steering committee and seven working groups (WGs) – WG1: Wind Conditions; WG2: Wind Power Systems; WG3: Wind Energy Integration; WG4: Offshore Development and Operation; WG5: Wind Markets and Economics; WG6: Wind Policy and Environment; and a Finance WG. This was the original organizational structure as it had evolved since October 2006.

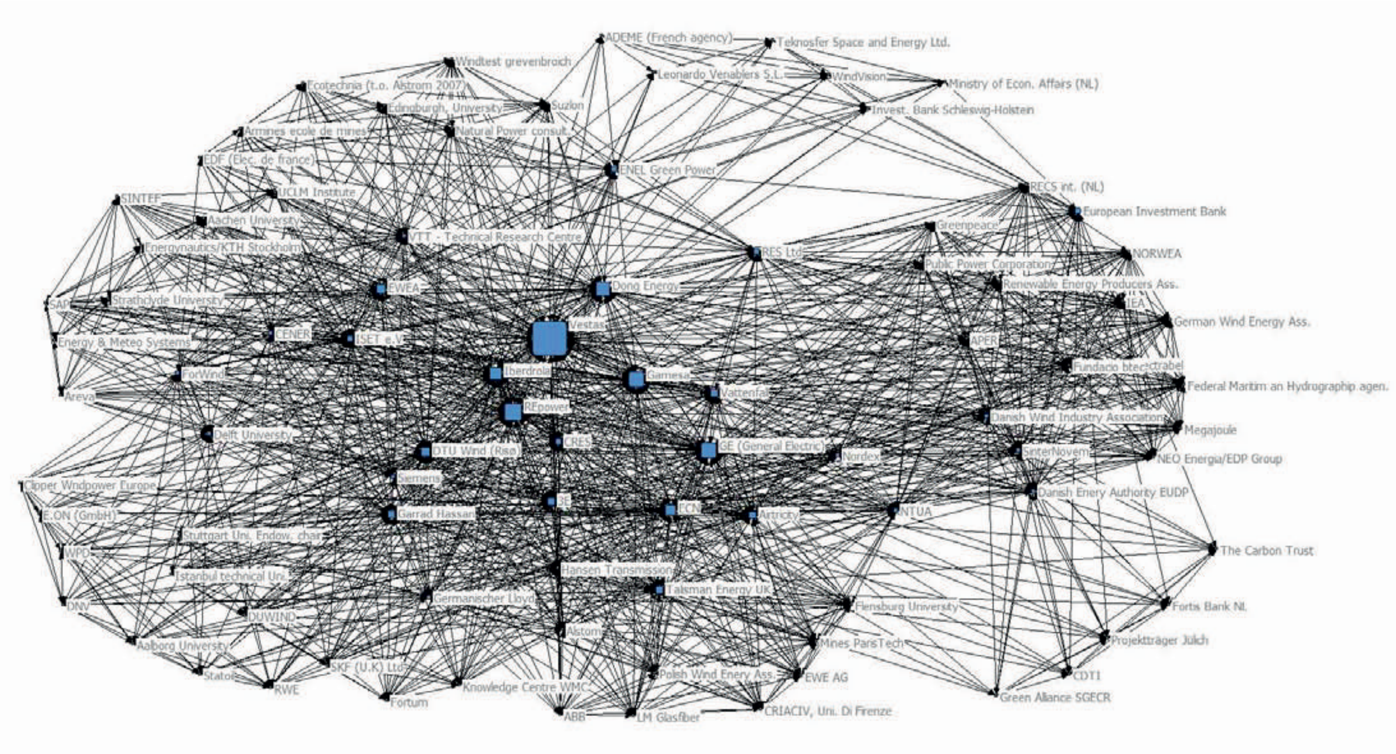
Then, after the first publication of the strategic research agenda and common vision, the organizational structure changed, starting in November 2007, into the organizational structure that forms it today, in November 2011. It now comprises the steering committee and the WGs – WG1: Wind Conditions; WG2: Wind Power Systems; WG3: Grid Integration: WG4: Offshore; WG5: Environment & Deployment. The main changes are in the working groups. A complete dataset was gathered on the membership of each of the working groups and the steering committee. Now, the executive committee consists only of three individuals who are also members of the steering committee, which consists of twenty-four individuals. The steering committee is the official management body; the executive committee could be excluded, since it is captured in the steering committee.

The networks from 2007 and 2011 can then be visualized using Netdraw (Borgatti et al., 2002). In figure 3.3.1, the two networks are visualized. Even though the total population of organizations has diminished slightly from 91 in 2007 to 88 in 2011, the networks have grown in size, making the organizations more connected and collaboration high. The betweenness measurement is then added to the visualization in figure 3.3.1, thus adding more information as more organizations have grown into being better positioned in the networks, between important organizations, so as to make the knowledge flow. These are the brokers, the high influencers and also the decision makers. This tells us that the power has become more evenly distributed since 2007, as the leadership is shared between more organizations.

Figure 3.3.1. Visualization of TPWind network – 2007 (top) and 2011 (bottom)*

*Ties are collaboration; nodes are organizations. The sizes of nodes are set proportional with betweenness measures: also known as 'brokers' in the network and power as decision makers.

TPWind November 2007



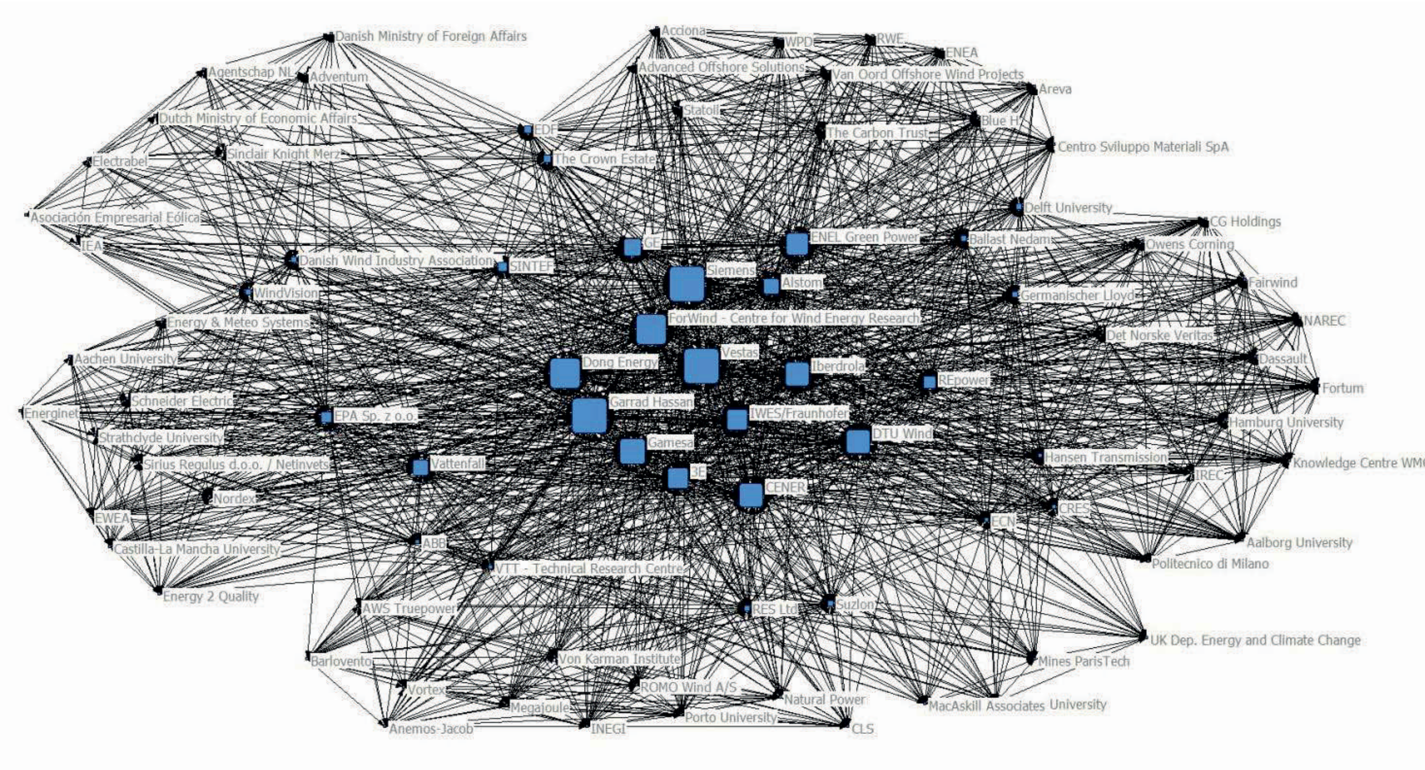

Danish Ministry of Foreign Affairs
Agentschap NL
Adventum
Dutch Ministry of Economic Affairs
Sinclair Knight Merz
Electrabel
Asociación Empresarial Eólica
IEA
Danish Wind Industry Association
WindVision
Energy & Meteo Systems
Aachen University
Schneider Electric
Energinet
Strathclyde University
Sirius Regulus d.o.o. / Netinvets
Nordex
EWEA
Castilla-La Mancha University
Energy 2 Quality
EDF
The Crown Estate
SINTEF
EPA Sp. z o.o.
Vattenfall
ABB
VTT - Technical Research Centre
AWS Truepower
Barlovento
Vortex
Anemos-Jacob
Megajoule
INEGI
Von Karman Institute
ROMO Wind A/S
Porto University
Natural Power
CLS
RES Ltd
Suzlon
Acciona
WPD
RWE
ENEA
Advanced Offshore Solutions
Van Oord Offshore Wind Projects
Areva
Statoil
The Carbon Trust
Blue H
Centro Sviluppo Materiali SpA
Delft University
CG Holdings
GE
ENEL Green Power
Ballast Nedam
Owens Corning
Siemens
Alstom
Germanischer Lloyd
Fairwind
ForWind - Centre for Wind Energy Research
NAREC
Det Norske Veritas
Dong Energy
Vestas
Iberdrola
Dassault
REpower
Fortum
Garrad Hassan
IWES/Fraunhofer
Hamburg University
DTU Wind
Gamesa
Hansen Transmission
Knowledge Centre WMC
3E
IREC
CENER
CRES
ECN
Aalborg University
Politecnico di Milano
UK Dep. Energy and Climate Change
Mines ParisTech
MacAskill Associates
University

Table 3.3.1 presents a top-five in calculations of both betweenness and degree so as to compare the changes in power. It tells us that Vestas, a Danish wind turbine manufacturer, had the leadership in the beginning of its establishment up to 2007, closely followed by Repower, also a wind turbine manufacturer being between important actors (betweenness) and Gamesa, a Spanish wind turbine manufacturer being very active in the network (degree).

Table 3.3.1. TPWind: Changes in 'Leadership' (top 5, centrality)

2007		**2011**	
Degree	**Between**	**Degree**	**Between**
1. Vestas (86.000)	1. Vestas (530.991)	1. Siemens (88.000) Vestas Garrad Hassan	1. Siemens (171.807) Vestas (Garrad Hassan)
2. Gamesa (72.000)	2. Repower (226.779)	2. DONG Energy ForWind (84.000)	2. DONG Energy ForWind (147.588)
3. General Electric (GE) (69.000)	3. Gamesa (211.168)	3. DTU Wind (80.000) CENER Iberdola	3. DTU Wind (113.781) CENER Iberdola
4. Repower DONG Energy (64.000)	4. General Electric (GE) (220.160)	4. 3E (76.000)	4. ENEL Green Power (99.934)
5. Iberdola (54.000)	5. DONG Energy (173.682)	5. ENEL Green Power (72.000)	5. 3E (94.895)

Hereafter, a much stronger focus on offshore wind power plants made Siemens Wind Power in 2011 an important and powerful player in the network. The power was now evenly distributed between Vestas, Siemens and Garrad Hassan, the last also being part of the secretariat, which is evenly divided between DTU Wind at Technical University of Denmark and the European Wind Association (EWEA) that is the European wind industry's interest group. Not surprisingly, Siemens Wind Power is particularly strong in manufacturing offshore wind turbines, and Siemens industries in producing electrical control systems, which are needed for the wind power plants. Both Vestas and Gamesa seem to have been falling behind the aggressive offshore strategy focusing on their expertise in manufacturing onshore wind turbines. In May 2012, Gamesa announced that the Spanish manufacturer's first offshore prototype is ready to be launched, and Vestas has indeed played catch-up with its competitors since its launch of the 6-megawatt offshore wind turbine in 2011 and the early annunciation of the 7-megawatt offshore (biggest turbine ever), securing its position. In second place, Dong Energy, a Danish utility company that within the last three years has focus on specializing in building offshore wind power plants. During the period of study, the Danish utility company moved from its fifth place to be a fast mover in building offshore wind farms, and closing in on the leadership of the manufactures. The change in leadership therefore seems to change, when problems change, following skills and experience in new strategic directions.

TPWind Core/Periphery over a four-year period

The analyses run for the 91 organizations in 2007 and for the 88 organizations in the sample for 2011 were iterated 50 times. In both networks, there was a partition of a core and periphery, placing organizations in the two groups. Results are shown in table 3.3.2.

Table 3.3.2. Core/Periphery

TPWind 2007-2011	Nov. 2007	Nov. 2011
Size of population	91	88
Size of core/periphery	23/68	17/71
Density in core	1.671	3.551
Density in periphery	0.456	0.238
Density of core to periphery	0.163	0.949

Comparison of the two results of the partition showed that the core has become denser. This indicates that there are members that meet more frequently over time, but it also indicates that the density from core to periphery is higher – making mobility easier in moving from core to periphery and from periphery to core. How has it changed? Which organizations are in the core? How many are the same? How many are new? How many have moved to the periphery, and who is out? The transition matrix in table 3.3.3 is based on the results from the core/periphery analysis. By performing a structured account, it was possible to track changes. The count included the newcomers and therefore provides a dynamic picture of changes in TPWind over a 4-year time span.

<table>
<tr><th colspan="6">Table. 3.3.3. TPWind Transition Matrix</th></tr>
<tr><td rowspan="5">Nov. 2007
P = 91</td><td colspan="5">Nov. 2011, P = 88</td></tr>
<tr><td>(number), %</td><td>Core
(18)</td><td>Periphery
(70)</td><td>Out</td><td rowspan="3">Out in total (48)
52.7</td></tr>
<tr><td>Core (23)</td><td>(14) 60.8</td><td>(5) 21.7</td><td>(4) 17.4</td></tr>
<tr><td>Periphery (68)</td><td>(2) 11.1</td><td>(22) 31.4</td><td>(44) 64.7</td></tr>
<tr><td>New</td><td>(2) 11.1</td><td>(43) 61.4</td><td colspan="2">New in total (45) 51</td></tr>
</table>

Of the 23 organizations in the core in 2007, only 14 remain the same, accounting for 60.8 percent. Five of those in the core in 2007 moved in 2011 to the periphery, while four organizations are out of the network. In total, there are 45 new organizations in the network, accounting for more than a 50 percent change in the network, which means that 48 organizations had left the network An example of a newcomer is Norwegian Veritas (DNV): The company had moved into the wind industry using its existing knowledge of offshore energy and its maritime history to specialize in standards of offshore wind turbines. Another example is IWES, the Fraunhofer Institute for Wind Energy and Energy System Technology, which is especially strong in offshore wind and a newcomer entering the core in 2011. This research institute was founded in 2009 as a merger of smaller research institutes in Germany. Others are Risoe, the wind research flagship of Denmark that merged with Technical University of Denmark in 2007; and Ecotechnia', which was a Spanish wind turbine manufacturer in the periphery in 2007 but sold the same year to Alstrom for 350 million Euros. This made it possible for Alstom to enter the wind industry with the model 'Alstrom Echotecnia' as their most powerful offshore wind turbine. The examples are innumerable. Some of the changes are due to natural life cycles, where individuals representing an organization are retired or simply change jobs. This a natural selection process, where skills and experience are transferred via job markets.

3.4. ZEP network analysis over a four-year period

The Zero Emission Fossil Fuel Power Plant Platform, also known as ZEP, deals with the Carbon Capture and Storage (CCS) Technology. The focus of ZEP is on deployment of CCS; therefore, the vision is also commercial. CCS should be commercially available before 2020, enabling fossil fuel power plants to be part of the low carbon economy (Christensen, Chief Geologist of Vattenfall, personal communication, 2009). ZEP is mainly driven by industry and includes large utility companies, suppliers, oil and gas companies and specialized smaller engineering companies involved in chemical processes. The platform was formed in October 2005 with an Advisory Council consisting of 25 individuals, which composes the management body. The five working groups (WGs) are WG1: Plants and CO_2 Capture; WG2: CO_2 Use and Storage; WG3: Infrastructure and Environment; WG4: Market, Regulation and Policy; WG5: Communication and Public Acceptance.

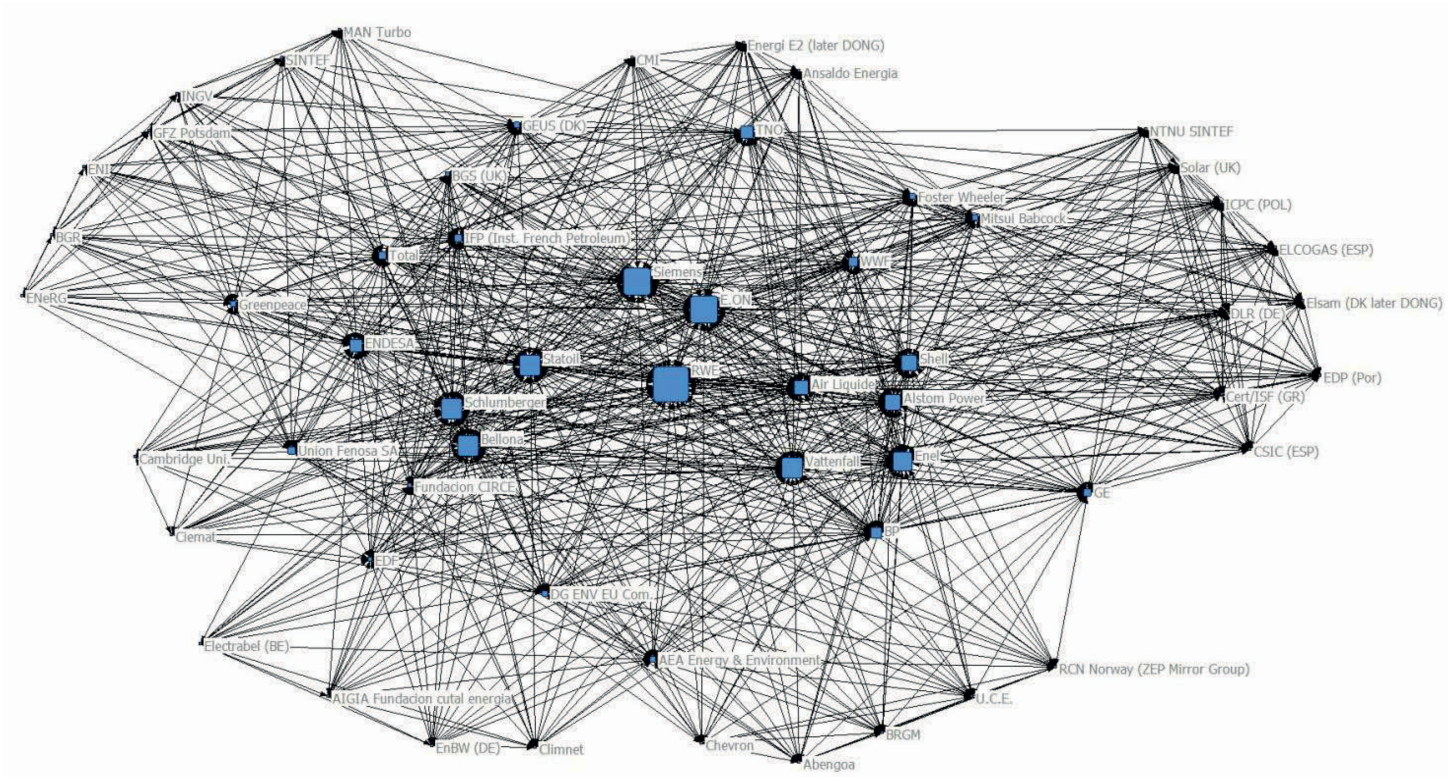
At the end of 2006, the finalizing of the strategic research agenda and strategic deployment documents was an eye-opener that required restructuring the working groups (Christensen, CEO and Chief Geologist of Vattenfall, personal communication, 2009, 2010; Sweeney, ZEP chairman, Executive Vice President, Shell, Future Fuels & CO2, personal communication, 2011). The main challenges were that of commercial viability, public acceptance and storage liability. A shift in focus from development to implementation was required, and approximately from March 2007, the working groups was divided into four taskforces – TF1: Technology; TF2: Demonstration and Implementation; TF3: Policy and Regulation; TF4: Public Communication. Call for qualified applicants for each taskforce was made in 2007 via the ZEP platform and network.

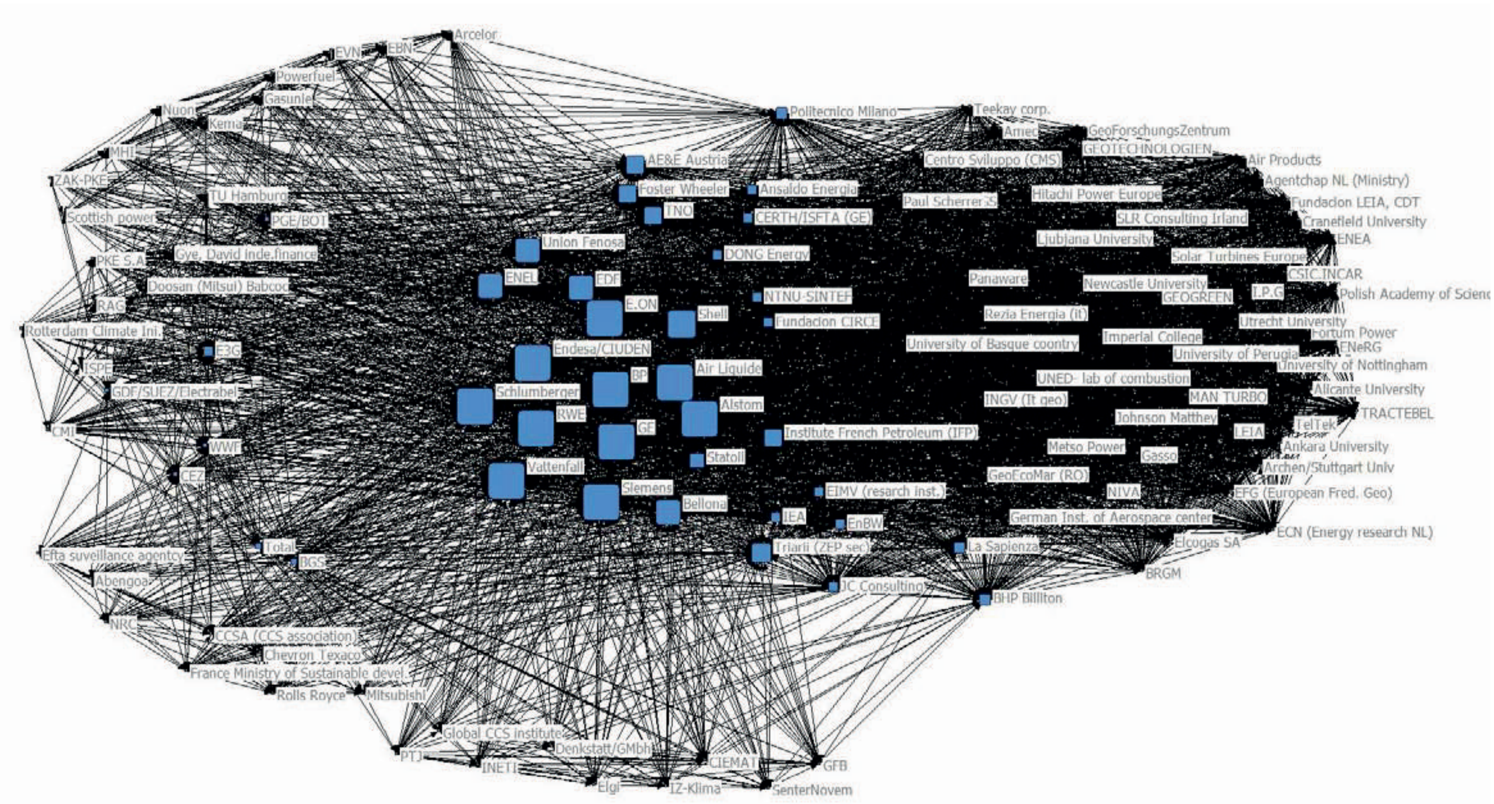
The networks of 2006 and 2011 can be visualized, again using Netdraw. In figure 3.4.1, the networks are visualized, and the visual comparison shows a network that has grown extensively, not only in size with more organizations and ties, making the organizations more connected, but it has also become a much denser network, indicating high collaboration. The betweenness centrality measure is then added to the visualization in order to find the brokers.

Figure 3.4.1. Visualization of ZEP Network – Nov. 2006 (top) and Nov. 2011 (bottom)*

*Nodes are set to be proportional with the analysis of 'betweenness' measure.

ZEP November 2006




Arcelor
EBN
EVN
Powerfuel
Gasunie
Nuon
Kema
MHI
ZAK-PKE
TU Hamburg
Scottish power
PGE/BOT
PKE S.A.
Gye, David inde.finance
Doosan (Mitsui) Babcoc
RAG
Rotterdam Climate Ini.
E3G
ISPE
GDF/SUEZ/Electrabel
CMI
WWF
CEZ
Efta suveillance agentcy
Total
BGS
Abengoa
NRC
CCSA (CCS association)
Chevron Texaco
France Ministry of Sustainable devel.
Rolls Royce
Mitsubishi
Global CCS institute
Denkstatt/GMbH
PTJ
INETI
Elgi
IZ-Klima
CIEMAT
GFB
SenterNovem
Politecnico Milano
AE&E Austria
Foster Wheeler
TNO
Ansaldo Energia
CERTH/ISFTA (GE)
Union Fenosa
DONG Energy
ENEL
EDF
E.ON
NTNU-SINTEF
Shell
Fundacion CIRCE
Endesa/CIUDEN
Air Liquide
BP
Schlumberger
Alstom
RWE
GE
Institute French Petroleum (IFP)
Statoil
Vattenfall
Siemens
EIMV (resarch inst.)
Bellona
IEA
EnBW
Triarii (ZEP sec)
JC Consulting
La Sapienza
BHP Billiton
Teekay corp.
Amec
GeoForschungsZentrum
GEOTECHNOLOGIEN
Centro Sviluppo (CMS)
Paul Scherrer S
Hitachi Power Europe
Air Products
Agentchap NL (Ministry)
Fundacion LEIA, CDT
Cranefield University
SLR Consulting Irland
Ljubljana University
ENEA
Solar Turbines Europe
Panaware
CSIC.INCAR
Newcastle University
GEOGREEN
I.P.G
Polish Academy of Scienc
Rezia Energia (it)
Utrecht University
Fortum Power
University of Basque country
Imperial College
ENeRG
University of Perugia
University of Nottingham
UNED- lab of combustion
INGV (It geo)
MAN TURBO
Alicante University
Johnson Matthey
TRACTEBEL
TelTek
LEIA
Metso Power
Gasso
Ankara University
Archen/Stuttgart Univ
GeoEcoMar (RO)
NIVA
EFG (European Fred. Geo)
German Inst. of Aerospace center
ECN (Energy research NL)
Elcogas SA
BRGM

To learn how the network has grown, the changes are detected through investigating the changes in 'leadership' through centrality measures. From the visualization of the betweenness, set as proportional with size of nodes, it is clear that the power is distributed differently. In table 3.4.1, a top five in betweenness (high influencers) and degree (connectors) is calculated in order to compare the changes in power. This tells us that RWE Power; a leading UK integrated Energy Company owning and building power utilities, had the leadership in 2006, and was at the same time a very active organization in the network. This position was closely followed by E.ON and Vattenfall. The network in 2006 was strongly driven by utility companies. In 2011, the network was driven by more companies sharing the 'leadership' and thus functioning as connectors, brokers and high influencers.

Table 3.4.1. ZEP: Changes in 'Leadership' (Top 5, centrality)

November 2006		**November 2011**	
Degree	**Between**	**Degree**	**Between**
1. RWE (1.018)	1. RWE (0.058)	1. Air Liquide Alstrom BP E.ON Endesa General Electric RWE Schlumberger Siemens Vattenfall 124.000)	1. Air Liquide, Alstrom, BP E.ON Endesa General Electric RWE, Schlumberger Siemens Vattenfall 165.417)
2. E.ON (0.947)	2. E.ON (0.045)	2. Shell (116.000)	2. Shell (125.081)
3. Vattenfall (0.895)	3. Siemens (0.042)	3. EDF (115.000) ENEL Union Fenosa	3. Bellona (110.853)
4. Schlumberger Statoil Bellona (0.860)	4. Vattenfall (0.033)	4. Bellona (114.000)	4. EDF (107.080) ENEL Union Fenosa
5. Enel (0.842)	5. Schlumberger Statoil Bellona (0.031)	5. AE&E Austria Foster Wheeler (107.000)	5. AE&E Austria Foster Wheeler (72.744)

New fast movers are Air Liquide, a world leader in gas processes for industry; Alstom, a global power supplier generating a quarter of the world's power; British Petroleum, a global oil and gas company that is also an innovator in biofuels and renewables but basically explores oil and gas, refines them and turns them into products; E.ON, a large utility company; Endesa, a large Spanish utility company; General Electric, also a large power supplier; Schumberger, a leading supplier of technology and management to customers working in oil and gas; Siemens, a large company supplier of products along the process chain from power generation to fuel-gas cleaning and CO_2 capture; Vattenfall, a large Swedish utility company; and Shell, a large oil company. Also Bellona, a Norwegian NGO, which does have sponsors from the industry but is quite open about it. Moreover, Norway has a strong oil and gas industry and is one of the few European countries that actually earn a large income from exporting oil and gas. These changes in connectivity are not surprising as they fit with the greater focus on climate change and reduction in CO_2 emissions. They also show a very collaborative network with strong players capable of investing in demonstration plants, which is one of the key problems in focus, since this change. Now, the second hypothesis to be investigated raises the question: Are there newcomers over time, or is it increasingly becoming the old boys' network?

ZEP Core/Periphery over a 5 year-period

The analyses run for the 58 organizations in 2006 and for the 124 organizations in the sample for 2011 were iterated 50 times. In both networks, there was a partition of a core and a periphery, placing the organizations in the two groups.

Table 3.4.2. Core/Periphery

ZEP 2006 – 2011	Nov. 2006	Nov. 2011
Size of population	58	124
Size of core/periphery	17/41	21/103
Density in core	3.029	3.557
Density in periphery	0.277	0.436
Density of core to periphery	0.867	1.080

Results in table 3.4.2 surprisingly show that core density is almost status quo – the network has from the beginning been based on key actors with a high frequency of interaction. According to the theory of Burt (1992) it is important also to analyze if there are newcomers within the network, if there are changes or transfer between clusters. I therefore use ta transition matrix.

The calculations of the transition matrix in table 3.4.3 are based on the total population of 58 organizations in November 2006 and 124 in November 2011. The cluster analysis of core/periphery present a structured account of which organizations are in the core, how many are the same, how many new, how many have moved to the periphery, and who is out. The figures also include the newcomers and therefore provide a picture of changes in ZEP over a 5-year time span.

Table 3.4.3. Transition matrix of ZEP, Nov. 2006 – Nov. 2011

	Nov. 2011, P = 124				
	(Number), %	Core (21)	Periphery (103)	Out	Total
Nov. 2006 P = 58	Core (17)	(14) *88, **66	(2) 2	(1) 2	Out in total (16) 26
	Periphery (41)	(5) 24	(21) 51	(15) 15	
	New	(2) 10	(80) 64.5	New in total (82) 66	

*Indicates number divided by number of organizations in core 2006, while ** indicates the number divided by number of organizations in core 2011.

In total, it has a steady core of *88 percent, while there is expansion of new members in the network (58/124) close to 46 percent. Accounting for the expansion of the members in the core – it gives a core solidness of *66 percent and therefore a dynamics of 34 percent, while periphery has a dynamics of 58 percent. The number of newcomers, including the organizations that move from core to periphery and from periphery to core (82 organizations), is close to a dynamics of 66 percent. Examples of organizations that have left the ZEP are Greenpeace, which changed its strategy to support only renewables. Even though, on one hand, ZEP mainly consists of large firms – which seem natural since the main focus is on large-scale demonstration plants to prove viability

– on the other hand, it does include many engineering companies specializing in chemical processes related to gasses like hydrogen and solar power. Techniques of CO_2 removal: post-combustion, pre-combustion, and oxy-fuel techniques are ironically related to the techniques of solar power and oxygen processes in hydrogen and fuel cells. These techniques may be a solution to make CCS cost competitive, or perhaps it is the other way around? Because that is the thing about innovation – we never really know.

3.5. Findings and discussion

In the second part of the analysis, I used the idea of 'innovation systems' in relation to the ETPs, seeing them as representing this idea. I investigated the organizational structure of the ETPs between two given periods: before 2007 and 2011, to test if there were any dynamics in the innovation systems.

For this to be structured, I used the results from the SNA that calculated the members belonging to the core and the periphery of the two networks between 2007 and 2011. To systemize the analysis, I recording all the changes in the member structure, and to analyze the results, I created a 'transition matrix' to count the changes in the core and periphery of the networks during the period. This also helped me visualize the results and show the changes and number of newcomers in the transition process.

Mapping all the members over this period of time showed that small firms also participated, but when they later left in 2011, the newcomer was a large incumbent firm. Following the lead, it turned out that one example taken from TPWind was Ecotechnia, a Spanish wind turbine manufacturer that was in the core/periphery in 2007 but was sold the same year to Alstrom for 350 million euros, making it now possible for Alstom to enter the wind industry with the 'Alstrom echotecnia' model as their most powerful turbine. Alstrom then entered the core of TPWind in 2011. Another example shows that it is not only firms that change, but also institutions. Riseo, the Danish national laboratory for renewable energy, was part of the core in 2007; it later merged with Technical University of Denmark and thus entered the core in 2011.

Networks are constantly changing – the measurements only reflect the activities at the given time, and the analysis is too sparse to generate any measurements on the basis of technology policy. Longitudinal studies are much more interesting from an evolutionary perspective, as they tell the story of how a specific innovation revolves around certain problems and transforms the connectivity between components as problems are discovered – a so-called learn-and-adapt knowledge process.

However, this does not say anything about the future transformation, since knowledge discovery and innovation are not a linear process. What it does tell us, in this case, is that the technology roadmap 2020 is a social construction, shaped by the actors involved according to their best knowledge leading to the discovery of new rules combined with their interest and power to mobilize human capital. If the promising R&Ds fail to deliver, it could therefore be concluded from a system perspective that maybe 1) a problem is missing; or 2) a stakeholder group is missing, e.g. universities, industry, the public etc.; or 3) maybe the R&D is simply not that promising.

System thinking and market failure perspectives on technology policy are inherently distinct. Encouraging and supporting the establishment of networks around central technologies that can change current systems involves a 180-degree turn from the idea of market failure that has been the dominating rationale for science and technology policy. It is the idea of seeing the economy as a system, as indicated by the quote from Metcalfe in the introduction; therefore, innovation may also be seen as systemic innovation, meaning that a change in one part of the system necessarily leads to corresponding change in another part of the system. With regard to learning from this case study, using the metaphor of systemic innovation, especially two points come to mind: One is that innovation has a value chain, and the second is that innovation goes beyond the value chain. This especially is one of the issues where the idea of market failure falls short. A policy perspective based on this idea would see opportunities as simply being out there for firms to discover, whereas system-thinking policy would see connectivity between organizations and institutions as the important infrastructure for shaping and creating opportunities.

Our learning from the case study of the ZEP platform, with focus on the issue of zero emission from fossil fuel power plants, tells a story of an innovation system evolving around a certain problem. In this context, the companies and institutions are highly linked to other organizations, not only within the technological domain, but also to NGOs, banks, and policy experts. Collaboration and knowledge sharing is high, despite superior technology and competitive advantage. The stakes are higher for driving the CCS-technologies forward with the narrow window of being commercially viable in 2020 than they are for holding on to knowledge – knowledge sharing and learning is therefore pushed to a much more effective level by aligning forces and sharing visions while remaining separate units that are moving toward maintaining the balance between distance and cohesiveness without leaving the innovation system – as elegant as the flocking instinct itself in a flock of birds. The large firms in both wind and CCS are to be considered as key-players in driving the technology further. The evolutionary perspective tells the story over time of how the innovation system has core-players – the connectors, the decision makers, and the influencers; how it changes; and even how the management body changes over time. Some firms and research institutions are taken over by a larger organization and die out. And some firms, or even NGOs, leave the ETPs, because cohesion is not achieved. As mentioned, an example of this is Greenpeace, which was a co-member of ZEP from 2005 to 2007. Its being a member of the periphery, and then later not to be found, makes sense since their current strategy is no carbon at all. In line with the industry's member of ZEP, this eye-opener of public and political acceptance of CCS also changed the organizational structure (Sweeney, ZEP chairman, Executive Vice President, Shell, Future Fuels & CO2, personal communication, 2011).

Another example mentioned was the strong and dominating network location in TPWind 2007 of Vestas, the large Danish wind manufacturer, followed by Gamesa, the Spanish manufacturer. In 2011, the network position came to be shared with Siemens Wind Power, another large wind turbine manufacturer, as the direction of the innovation moved towards offshore wind power plants. The manufacturers' positions are closely followed by large utility companies. This is an historical perspective on how the position of the two networks changes and seemingly take advantage of the evolutionary benefits that the network provides. These benefits are:

- Combining knowledge and skills, which is necessary in a knowledge-specialized society, where organizations and individuals know a lot in very highly specialized fields

- Collective action in technological development, which allows spillovers to small and larger companies/research institutions, and increases the effectiveness of the innovation system

- Cohesion, a strong voice of the industry. Collective action allows a more visible and therefore also a stronger voice when politicians are to make regulatory and financial framework decisions

When taking the technologies to the commercial stage, the small companies are usually not equipped to deliver. This problem brings up the relevant topic of the role of the large firms in driving innovation, and very much relates to the Schumpeter Mark II type of innovation. The capitalists' interests are the driving force in the economy – do not make the mistake of interpreting the value chain in any other romantic way. The real mistake, which is augmented by social science scholars and particularly sociologists, is to ignore that these economic interests are deeply embedded in social relations.

These new innovation policy instruments are also an introduction to new mechanisms in the economy, since their presence and recognition, and the strong voice of the industry, change the rules of the game; it is the concept of systemic innovation, which thus introduces the macro-meso-micro-architecture. And placing the ETPs on the meso-level tells us something about how firms and institutions work from within the political system to create new business opportunities *and* institutional structure in the economy. It therefore also tells us that the innovation policy perspective based on system thinking has implications in terms of new instruments. The implications of these are yet to be discovered, but so far this study points to the following:

- Firms and institutions work *from within* the political systems to create their own futures by constantly challenging the path being followed, analogous to Schumpeter's creative destruction
- Innovation systems have key players. These players have strong interests but are socially accepted as key players, connectors, brokers and decision makers, based on skills, knowledge, and experience.

Based on the findings of the analysis, this paper argues that connectivity in innovation systems revolves around certain problems. In the case of the CCS technology, connectivity in the early phase of the study evolved around technological problems. However, after the formation of the ZEP platform, which brought key stakeholders together, it was clear that the main obstacle was and still is: political and public acceptance of CO_2 storage, proof of its viability, and advising about and advocating for regulatory frameworks (Sweeney, ZEP chairman, Executive Vice President, Shell, Future Fuels & CO2, personal communication, 2011). The TPWind platform believes that the expansion of the wind industry involves moving off shore, which will solve the public acceptance problem of 'not in my backyard'. At the same time, it will make the wind resource more efficient. Connectivity will change as knowhow and knowledge regarding reducing costs comes from competing industries. Since the oil and gas industry has a huge amount of experience with off-shore power platforms, there is good reason for collaboration at the collective level (Kruse, TPWind chairman, Director Government Affairs, Siemens Wind Power, personal communication, 2010).

The findings therefore support the theoretical assumptions that the research aimed to investigate – that it is relevant to include both systemic properties and evolutionary properties in technology and innovation policy – that if you change the rules of the game that define the order, you naturally also change that order on which the rules are based, thus creating a new instituted frame within which systems can evolve. This is co-development.

3.6. Conclusion

The methodology demonstrates a social network analysis situated within the idea of evolutionary economic analytical framework and the idea of dynamic innovation systems.

The value of this study, which provides results of a structural change analysis, is its support of the thesis that systems of innovation evolve around certain problems – meaning that they are dynamic. The present analysis could only be made as a core/periphery analysis over time – examining changes between two important periods of time – just before a period of organizational change due to changes in problems and in the core/periphery of the network. One cannot simply measure the functionality of a network at one given time and draw policy conclusions, because the network's connectivity seems to be constantly changing along with the identification of current problems/barriers. Furthermore, the analysis showed changes in leadership of the platform. Certainly, there is a chairman, but the leadership of the platform is more than one person. The author therefore chose to investigate the whole structure, including working groups and task forces. The decision makers, those with a network location between important actors, and therefore those who play a powerful role in the network, are still in the core, but the organizations change positions in being leaders, following skills and vision according to strategic direction. In both platforms, there are changes in the core and the periphery and many newcomers.

The analysis therefore supports the hypothesis that the systems evolve around certain problems; when there is a change in the problem, connectivity changes in a way that makes sense for solving the problem. The analysis also seems to support the open system theory, thus emphasizing the importance of newcomers, which also includes the mobility of organizations that move between core and periphery.

The findings of the case studies of the European Technology Platforms in wind power and in carbon capturing and storage revealed a paradox of collective innovation and vision sharing versus firms seeking asymmetric information. This paradox also shows that pragmatic action at the collective level and firms seeking to maintain their competitive advantage relate very closely to the system thinking in the innovation system and evolutionary thinking. A basic assumption within evolutionary economics and the innovation system perspective is that firms do not innovate in isolation; the way the systems evolve relates to connectivity and the agents working around certain problems. Sometimes the problems change, or the agents find that the problem they are working with is not really the problem; there is another problem and, systemically, the connectivity changes. Transferring the theoretical concept of system thinking to the industry-led ETPs is much related to the important role of connectivity and to entrepreneurship, in the sense that these industrial-led technology platforms provide insight into how future technological trajectories towards a low carbon economy are being shaped in interaction between EU policy makers and the incumbent firms, which is very much related to Schumpeter's Mark II innovation. However, the social actions, and the work around path creation (the roadmaps) comprise a step from the entrepreneur at the individual level towards entrepreneurial activities at a more collective level and within an economic system and specialized knowledge society, where connectivity and network-like relations, as opposed to arm-length anonymous interactions as presumed in neoclassical thinking, play an important role in innovation.

3.7. Implication for innovation policy

Instead of seeing opportunities as something out there for the firms to explore, this framework sees the importance of connectivity in a highly specialized knowledge economy. Innovation policy instruments may be seen as supportive in establishing infrastructures and mobility for organizations, institutions and firms in their exploration of innovation opportunities. Interest, knowledge and skills are key drivers of key stakeholders, and must be dealt with in a transparent manner. The ETPs are new instruments of innovation policy, and using the concept of systemic innovation, these new institutions change the rules of the game. The study of the ETPs not only tells us something about key institutional characteristics, but also how these are constantly changing; in other words, how firms and institutions work from within the political system to create new business opportunities and institutional structures in the economy, while shaping and unfolding technological trajectories around specific major societal problems in important ways.

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3.9. Appendix: Core/Periphery Class Memberships

1= core, 2= periphery

TPWind November 2007

1(core): 3E Airtricity Alstom CENER CRES Dong Energy DTU Wind (Risoe) ECN EWEA Gamesa Garrad Hassan GE (General Electric) Germanischer Lloyd Hansen Transmission Iberdrola ISET e.V Nordex NTUA REpower Siemens Talisman Energy UK Vattenfall Vestas

2 (periphery): ABB ADEME (French agency) Armines ecole de mines APER Areva CDTI Clipper Wndpower Europe CRIACIV, Uni. Di Firenze Danish Enery Authority EUDP Danish Wind Industry Association Delft University DNV DUWIND Ecotechnia (t.o. Alstrom 2007) E.ON (GmbH) Edingburgh, University EDF (Elec. de france) Electrabel ENEL Green Power Energy & Meteo Systems Energynautics/KTH Stockholm European Investment Bank EWE AG Federal Maritim an Hydrographip agen. Flensburg University Fortis Bank NL Fortum ForWind Fundacio btec Greenpeace German Wind Energy Ass. Green Alliance SGECR IEA Invest. Bank Schleswig-Holstein Istanbul technical Uni. Knowledge Centre WMC Leonardo Venablers S.L. LM Glasfiber Megajoule Mines ParisTech Ministry of Econ. Affairs (NL) Natural Power consult. NEO Energia/EDP Group NORWEA Polish Wind Enery Ass. Projekttrager Julich Public Power Corporation Renewable Energy Producers Ass. RECS int. (NL) RES Ltd RWE SAP SinterNovem SINTEF SKF (U.K) Ltd Statoil Strathclyde University Stuttgart Uni. Endow. chair Suzlon Teknosfer Space and Energy Ltd. The Carbon Trust UCLM Institute VTT - Technical Research Centre WindVision Windtest grevenbroich WPD Aachen University Aalborg University

TPWind November 2011:

1: 3E Alstom CENER Dong Energy DTU Wind ENEL Green Power ForWind - Centre for Wind Energy Research Gamesa Garrad Hassan GE Iberdrola IWES/Fraunhofer REpower Siemens SINTEF Vattenfall Vestas

2: ABB Acciona Advanced Offshore Solutions Adventum Agentschap NL Anemos-Jacob Areva Asociacion Empresarial AWS Truepower Ballast Nedam Barlovento Blue H Castilla-La Mancha University Centro Sviluppo Materiali SpA CG Holdings CLS CRES Danish Ministry of Foreign Affairs Danish Wind Industry Association Dassault Delft University Det Norske Veritas Durham University Dutch Ministry of Economic Affairs ECN EDF Electrabel ENEA Energinet Energy & Meteo Systems Energy 2 Quality EPA Sp. z o.o. EWEA Fairwind Fortum Germanischer Lloyd Hamburg University Hansen Transmission IEA INEGI IREC Knowledge Centre WMC MacAskill Associates Megajoule Mines ParisTech NAREC Natural Power Nordex Owens Corning Politecnico di Milano Porto University RES Ltd ROMO Wind A/S RWE Schneider Electric Sinclair Knight Merz Sirius Regulus d.o.o. / Netinvets Statoil Strathclyde University Suzlon The Carbon Trust The Crown Estate UK Dep. Energy and Climate Change Van Oord Offshore Wind Projects Von Karman Institute Vortex VTT - Technical Research Centre WindVision WPD Aachen University Aalborg University

ZEP 2006 – before March 2007

1: Air Liquide Alstom Power Bellona BP Climnet E.ON ENDESA Enel IFP (Inst. French Petroleum) RWE Schlumberger Shell Siemens Statoil Total Vattenfall WWF

2: Abengoa AEA Energy & Environment AIGIA Fundacion cutal energia Ansaldo Energia BGR BRGM BGS (UK) Cambridge Uni. Cert/ISF (GR) Chevron Ciemat CMI CSIC (ESP) DG ENV EU Com. DLR (DE) EDP (Por) Electrabel (BE) Elsam (DK later DONG) EDF EnBW (DE) Energi E2 (later DONG) ENeRG ENI ELCOGAS (ESP) Foster Wheeler Fundacion CIRCE GE GEUS (DK) GFZ Potsdam Greenpeace ICPC (POL) INGV MAN Turbo Mitsui Babcock NTNU SINTEF RCN Norway (ZEP Mirror Group) SINTEF Solar (UK) TNO U.C.E. Union Fenosa SA

ZEP 2011:

1: AE&E Austria Air Liquide Alstom Bellona BP E.ON EDF Endesa/CIUDEN ENEL Foster Wheeler GE Institute French Petroleum (IFP) RWE Schlumberger Shell Siemens Statoil TNO Triarii (ZEP sec) Union Fenosa Vattenfall

2: Abengoa Agentchap NL (Ministry) Air Products Alicante University Ankara University Ansaldo Energia Amec Arcelor Archen/Stuttgart Univ BGS BHP Billiton BRGM CCSA (CCS association) Centro Sviluppo (CMS) CERTH/ISFTA (GE) Chevron Texaco CEZ CIEMAT CMI CSIC.INCAR Cranefield University DONG Energy Doosan (Mitsui) Babcoc Denkstatt/GMbh E3G EBN ECN (Energy research NL) Elcogas SA EFG (European Fred. Geo) Efta suveillance agentcy EIMV (resarch inst.) Elgi EnBW ENEA ENeRG EVN Fortum Power France Ministry of Sustainable devel. Fundacion CIRCE Fundacion LEIA, CDT Gasso Gasunie GDF/SUEZ/Electrabel GEOGREEN GeoEcoMar (RO) GeoForschungsZentrum GEOTECHNOLOGIEN German Inst. of Aerospace center GFB Global CCS institute Gye, David inde.finance Hitachi Power Europe IEA INGV (It geo) INETI Imperial College I.P.G ISPE IZ-Klima Johnson Matthey JC Consulting Kema La Sapienza LEIA Ljubjana University MAN TURBO Metso Power Mitsubishi MHI Newcastle University NIVA Nuon NRC NTNU-SINTEF OGS Paul Scherrer Panaware PGE/BOT PKE S.A Politecnico Milano Polish Academy of Science Powerfuel PTJ RAG Rezia Energia (it) Rolls Royce Rotterdam Climate Ini. Scottish power SenterNovem SLR Consulting Irland Solar Turbines Europe Teekay corp. TelTek Total TRACTEBEL TU Hamburg UNED- lab of combustion University of Nottingham University of Perugia University of Basque country Utrecht University WWF ZAK-PKE

4. Chapter four: From Future Scenarios to Roadmapping: A Practical Guide for Exploring Innovation and Strategy

This chapter builds on a brief (a short article, maximum 4 pages using a template) published by the European Foresight Platform in January 2012 as EFP Brief No. 207. It was originally an abstract submitted to the 4th International FTA conference, which was hosted by the European Commission, JRC, 13 -14 May 2011 in Seville, Spain. The brief is based on the idea of combining scenarios with roadmapping.

The EFP is financed by the European Commission DG Research. It is part of a series of initiatives intended to provide a 'Knowledge Sharing Platform' for policy makers in the European Union. More information on the EFP and on the Knowledge Sharing Platform is provided at www.foresight-platform.eu

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EFP Brief No. 207

Authors: Lykke Margot Ricard lmri@man.dtu.dk, lykkemargot@gmail.com

Kristian Borch krbo@man.dtu.dk

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Duration: N/A **Budget:** N/A **Time Horizon:** 2025 **Date of Brief:** Jan 2012

4.1. Purpose

This methodology brief describes a procedure where we combine scenarios that allow us to anticipate and prepare for multiple futures with the process of roadmapping serving as a systematic decision support tool. This specific foresight exercise, from scenarios to roadmapping, can be conducted as a one to two-day workshop with 20-30 lead engineers or managers to gather information in an organisation.

4.2. Visionary Approaches for Corporate Foresight

Managing technologies and strategic planning of business development goes hand in hand in today's knowledge economy. Business planning in the long run involves planning of emerging technologies as well as anticipating and preparing for disruptive change in economy and society. This involves tremendous uncertainties. Both scenarios and roadmapping are flexible tools fitted to deal with uncertainties. Scenario-making is one way of anticipating possible futures to make better decisions today. Yet, scenarios leave us with many plausible futures, thereby making it difficult to choose which path to follow as each scenario projects a storyline with emphasis on different drivers and ridden with uncertainties. Traditionally, scenarios have been developed to support the formulation of a vision and mission statement for the most desired path of development. However, scenarios have been criticised for being too distant to support strategy development. Roadmapping, on the other hand, is a very precise tool oriented towards decision-making in the present, but it may exclude important uncertainties as the focus is on one single future. The roadmap is a way to illustrate and communicate alignments of technology, product development and market requirements and the right timing guided by a common vision (Phaal et al., 2004 and 2009). Technology management literature defines it as visualising the strategy and showing the route from the current situation to the desired future (Goenaga and Phaal, 2009).

In general, roadmapping is described as a structural, yet flexible tool when navigating in a sea of uncertainties. However, we claim there is a weak point in roadmapping not dealt with in foresight or roadmapping literature, namely where the vision comes from. The reason could be that technology roadmapping so far has mostly been part of technology management where the vision is given. This may stand in opposition to strategic management where the vision is developed. For sure, a shared vision is a strong driver for any process. The vision may be developed by top management, but in organisations it is important to actually make it a shared vision leading to shared actions (eventually a driver for the mission statement).

While participatory scenario-making provides visions for multiple futures, a roadmap operates with one vision only. In this paper, we propose combining the flexibility of multiple visions of scenarios with action-oriented roadmapping.

4.3. Positioning of a Systematic Decision Support Tool

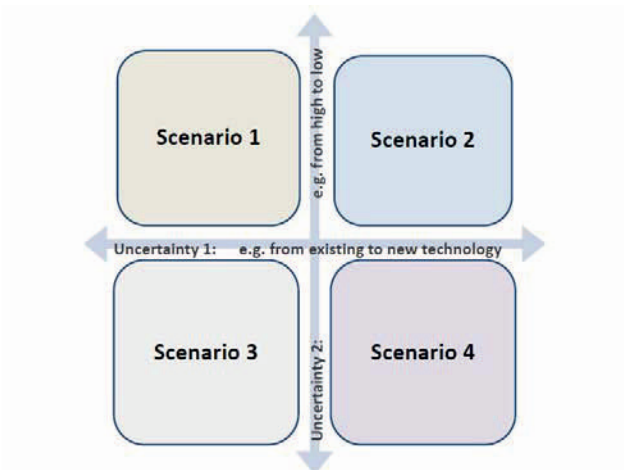
Only a few previous studies in foresight have dealt with the practical side of linking scenarios with roadmapping. Lizaso and Reger's article from 2004 provides a theoretical discussion of the value of linking roadmapping with scenarios for strategic technology planning. They describe a step-by-step process of creating scenarios to open up a variety of possible futures. However, they also perceive visions as desirable pictures of conceivable futures. Yet this is not necessarily so. In line with Saritas and Aylen's article from 2010 that roadmapping usually builds on one future and scenarios on multiple futures, we suggest that combining these methods will add value by exploring possible innovation paths and identifying knowledge gaps and critical decision-points at a given time, thus improving strategy-making. However, in contrast to Saritas and Aylen, who build one roadmap for each scenario, we use the scenarios to develop a common understanding, a common vision, which is a necessary requirement in a corporate setting.

This methodology therefore combines the four scenarios that allow us to anticipate and prepare for multiple futures based on a common vision, which serves as the driver for the roadmapping processes. Linking scenario-making to roadmapping involves moving from an exploratory study of possible futures towards a more goal-oriented strategic roadmap – meaning in *this case* that the scenario exercise is a playground for building visions.

4.4. From Four Visions to Consensus

Our point of departure is a group of lead engineers, technology managers or a division of a company – public or private – involved in exploring innovation and future developments (20-30 persons). The group has some insight in the present strategies of a company and the challenges it faces. The STEEPV acronym for the six themes of thinking about the future, social, technology, economics, ecology, politics and values, guides the search for future uncertainties (Loveridge, 2002; id. and Saritas, 2009). Examples are climate change, new technologies, political change and policy drivers, scarce resources (e.g. oil, gas and minerals), economic crisis, and social factors, such as demographic change, change in access to skilled staff, costumer needs etc. We use the STEEPV themes for trends and drivers up to 2025 to facilitate the construction of four future scenarios. The scenarios are constructed based on two identified uncertainties and a number of market drivers (Figure 1).

Figure 4.4.1. Four scenarios, two uncertainties



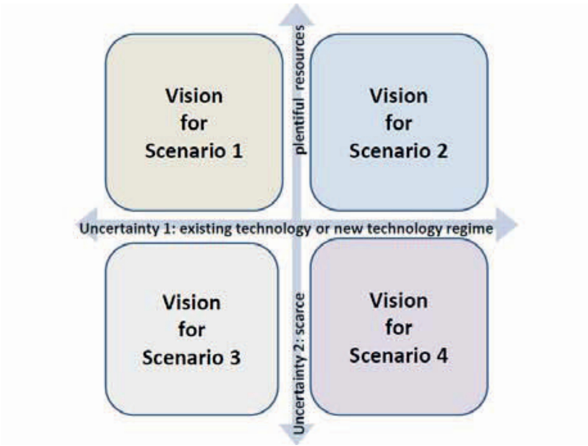
Managers justifiably involve experts in technology management to give technical and market advice, but often no one really exactly knows where technologies and markets are heading in the long run. This is where scenario thinking becomes important because it allows raising important questions:

Which set of multiple futures might be likely?

How can the company prepare for them?

The ***exercise*** divides the participants into four groups, a group for each scenario. The ***task*** is to give the scenario a name and formulate a short narrative formulated into a vision. A vision is explained as a desired picture of the company's position in each scenario given the uncertainties. Figure 2 illustrates the results.

Figure 4.4.2. Four scenarios, four visions



The next step is to synthesise the four visions into one common vision for the following participatory technology roadmapping exercise to build upon. Based on the four scenarios, the participants develop a common vision for the firm to meet the challenges envisaged up to 2025.

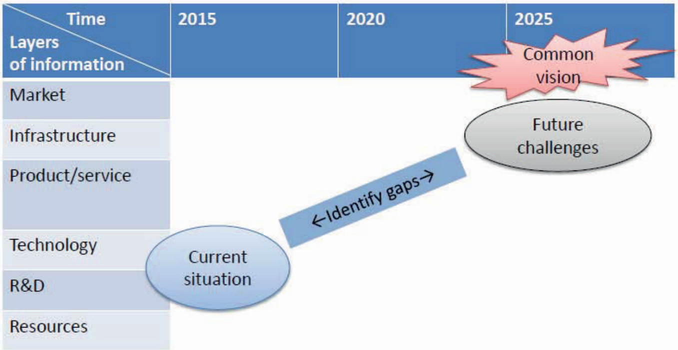
4.5. A Common Vision Is Developed in Plenum

The common vision exercise provides a bridge from the four scenarios to the explorative roadmapping process. It is based on a consensus process integrating the four visions from the scenarios into one shared vision. The common vision acts as the driver in the technology roadmapping process and provides guidance toward the desired future.

The group is then introduced to roadmapping, moving from an explorative strategic landscape towards a more goal-oriented technology roadmap. In plenum, the group is presented with a framework of the strategic landscape. The participants again apply the STEEPV themes, but this time they have a common vision and a timeline.

The common vision is placed in the framework to highlight the common direction. Post-its are placed along the timeline from the present up to 2025, aligning the layers as illustrated in the following figures. Brief comments and discussion are welcomed as the post-its are placed along the layers.

Figure 4.5.1. Identifying innovation gaps

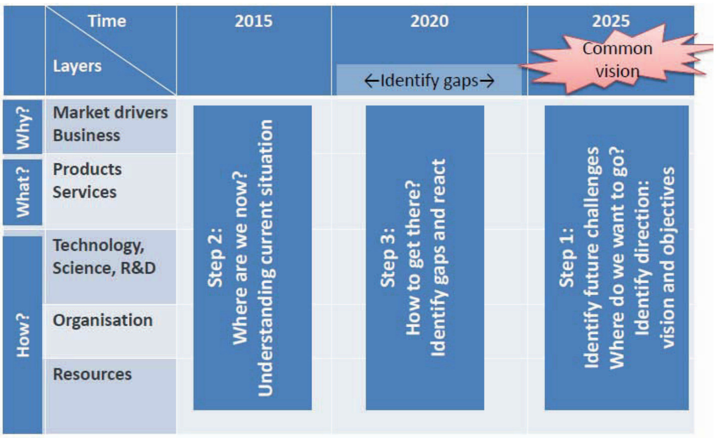


The outline in Figure 4.5.1 and 4.5.2. is adapted from (Phaal et al., 2009, Phaal and Muller, 2007 and 2009).

The information gathered using the post-its from the previous exercise is condensed into the plenum roadmap, and specific issues or new innovation ideas are placed, discussed and eventually ranked by each participant, placing a red dot on the most important ideas to be explored using the roadmap framework.

In our exercise, five technology roadmaps were developed, as there were five groups, providing five new ideas and five development paths for each idea or issue, which were in line with the common vision. The common vision should be seen as the key driver in the innovation process. In general, the roadmap provides a visual representation of layers of information related to developments of technologies in the context explored. The focus on condensing the complex information into one graphical framework is a key benefit of technology roadmaps, allowing to visualise market pull and technology push while checking for consistency in alignments of market and business drivers with product and services and R&D development to ensure the right timing for entering the market (Goenago-Larranaga and Phaal, 2010).

Figure 4.5.2. Design of the roadmap and structure



4.6. Manuel for a One-day Workshop: A Practical Guide to Our Methodology

First, we include a brief theoretical introduction to scenario thinking to create awareness among the participants for the social shaping of the future by showing the possibility of equally plausible alternative paths of development.

After the introduction follows a brainstorm session. First, each participant produces post-its for trends and drivers up to 2025 using the STEEPV themes as guidance. Thereafter, we conduct collective brainstorming in plenum where all post-its are placed on a large whiteboard. As facilitators, we cluster the post-its according to the STEEPV themes. The participants then vote on the most uncertain and most likely trends and drivers. The plenum consents on two drivers for constructing the scenarios. Using a simple matrix, the plenum constructs a framework for four scenarios up to 2025. Four groups work on constructing a scenario each based on one vision.

After the groups present each scenario and their vision, a consensus process in the plenum leads to formulating a consensual vision. The major value of this procedure is building cohesion around this common vision before introducing the roadmap framework. The roadmapping exercise works with two types: strategic landscape and technology roadmapping. The common vision is the driver for the roadmaps since it guides the process towards achieving a desired future. The participants vote to determine the five topics they consider most import to be explored via roadmapping.

Five ***technology roadmaps*** – one on each topic – are developed in newly formed groups. The roadmaps support identifying current knowledge gaps if the desired future is to be reached. The framework allows the participants to recognize challenges and critical decision-points that one needs be aware of to respond in time to windows of opportunity. The process ends by evaluating the exercises in plenum.

4.7. Meta-level Considerations

1. ***Learning from scenario-making***: We see scenarios as a creative way of inspiring innovation. The lesson to be learned from the scenarios is that the decisions made in the present are of strategic relevance to the future and thus actually part of shaping it since the long-term future is an open process. We therefore conclude that scenario thinking creates awareness of socially shaping the future by showing the possibility of equally plausible alternative paths of development in industry.

2. ***Learning point from the roadmap***: The point of the roadmap was to provide a strategic framework for aligning market trends and drivers with technology developments and setting priorities for R&D.

3. ***Combining scenario and roadmapping***: The value of combining scenario-building and roadmapping in this exercise is that scenarios allow us to anticipate and prepare for multiple futures while roadmapping enables identifying options for shaping a technology in more than one direction.

4. ***The strength of a common framework***: Our experience from using this guide testifies to the importance of familiarising the participants with the methodology as a flexible framework and exercise. All of the elements are key ingredients to bring together, for instance, lead engineers or stakeholders in an innovation system with the goal of developing a common vision, initiating innovation efforts, and aligning technology and innovation with trends and market drivers. The alignment supports decision makers in being able to effectively respond to market changes and create the right timing for a new technology. Of course, neither roadmapping nor scenarios are silver bullets. Scholars such as Rob Phaal (Phaal et al., 2003) have argued that the true value of roadmapping lies in the on-going process. We very much agree as roadmapping, albeit a strong tool for decision-making has no miraculous future-telling powers. As practitioners of strategic projects know, uncertainties change and competing or promising technologies sometimes fail to reach market.

4.8. Creating the Future through Visioning and Roadmapping

Linking scenarios with technology roadmapping initiates an exploratory and creative phase aimed at identifying and understanding uncertainties. Scenario-building creates awareness for the possibility of more than one future, each of which is equally plausible. Roadmapping provides a framework for condensing all information into a single map and timeframe – revealing windows of opportunity and thus linking decision-making with alternative futures. The step from scenario-building to technology roadmapping requires creating a common understanding of challenges and establishing a common vision. In exploring possible futures and visions, the participants are exposed to the basic assumption in foresight that the future in 20 years is open and it is possible to sense and seize opportunities and develop new technical and organisational skills or utilise existing ones.

An exercise of this kind can be conducted as a one-day workshop. However, we do recommend a two-day workshop since it leaves more time for group work and presentations. The role of the facilitator is of great significance; it is important to keep a positive attitude and perceive the workshop as an interactive learning process. Furthermore, the structured and systematic framework ensures a common context that makes facilitating the process easier. It may even provide a starting point for the participants to establish networks in the future based on this shared learning experience.

In conclusion, combining future scenarios and roadmapping can be useful in that the creativity provided by scenarios may help in making better decisions in developing the paths spelled out in the roadmap.

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5. Chapter five: Explorative Roadmapping Integrated with Dynamic Capability Thinking: Early stage strategizing on Novozymes' Albufuse® Flex technology

This chapter builds on an article submitted in July, 2012 to the journal of Technological Forecasting and Social Change. The article is in co-authorship with Julie Serritslev for whom I supervised on the business part of her master thesis in collaboration with Novozymes' Bio Business department using this new concept of integrating explorative roadmapping with Dynamic Capability thinking. The authors seek to combine the roadmapping approach taken from the technology management literature with the theory of dynamic capabilities taken from the Strategic management literature. The article is conceptual, but includes a case study with the experience of fitting the approach to the Novozymes Albufuse® Flex technology. It was an approach combining commercial perspectives with technological developments, and also an approach beyond business as usual. Some issues have been modified or left out as this are still confidential, but in overall the article give insight into an otherwise black box of commercialization and development of a new drug delivery technology.

*Lykke Margot Ricard[7] & **Julie Serritslev, Technical University of Denmark

*DTU Management Engineering, **DTU Systems Biology

Abstract

A large Danish biotech company that specializes in the production of industrial enzymes recently challenged us to analyze a commercialization strategy for a new biopharmaceutical technology. The challenge was to give a perspective beyond business as usual. The focus of this study is practical roadmapping integrated with capability thinking, which will, in a broad sense, enable strategy planning for commercialization. Such an approach has not been undertaken in the current academic literature. Therefore, we developed such a conceptual framework for the Albufuse® Flex technology, a 2nd-generation albumin fusion technology that offers the potential to enhance patient compliance and quality of life by tailoring of a drug's circulatory half-life. This case study was conducted between August 2010 and May 2011, providing a roadmap analysis on the Albufuse® Flex before this product was even patented and made public. It was an opportunity to challenge the academic foresight methodologies, when combining practical roadmapping with the theoretical

[7] Corresponding author, Lykke Margot Ricard, Management Engineering, LMRI@DTU.DK, lykkemargot@gmail.com

concept of dynamic capabilities. This article, therefore, aims to provide insight into an otherwise black-box area of methods and foresight tools for analyzing the potential of commercialization strategies guiding long-term investment in new technologies at firm-level, in this particular case, within a large biotech company.

Keywords: Corporate foresight; roadmapping; dynamic capabilities; commercialization; capability maps; biopharmaceutical; albumin; Novozymes

Acknowledgement

A large Danish biotech company that specializes in the production of industrial enzymes recently challenged us to analyze a commercialization strategy for a new biopharmaceutical technology. The authors would like to acknowledge the important support of the project by Senior Director of Novozymes BioPharma, Svend Licht, and his positive feedback in writing up this journal article deserves much credit. A special thanks to employees in Novozymes BioPharma and BioBusiness, who participated in interviews, discussions and workshops.

5.1. Introduction

Modern day technology companies are faced with an ever-changing macro-environment and fast developing competition: increasing pace in new technologies and regulation are just some of the influential changes in a firm's strategic environment. In order for a company to ensure economic growth and sustain its business for the long-term it needs to be capable of dynamically adapting to the changing environment it is surrounded by [1]. Such capabilities within a company has been called 'Dynamic capabilities" and is a recent add-on to the resource-based view of the firm [2]. Dynamic capabilities deal with the processes that allow companies to sustain competitive advantages in fast-moving technological environments, given its history and current stage. Dynamic capabilities are therefore the distinctive processes that facilitate not only the ability to recognize the technological changes in market environment, but also the processes of changing and shaping the company's asset positions in reaction to change. Dynamic capabilities is therefore closely related to a company's "performance", which according to Teece [3] is to create, deploy, and protect the intangible assets that support superior long- run business. It is therefore critical for managers who make strategic decisions to understand the main trends in the market and possible paths for technological development to improve their market predictions.

Though simple to use, linear innovation models tend to overlook feedback mechanisms from the market that otherwise would or could be integrated into the company's R&D development phase[8]. Practical roadmapping methods require the inclusion of these mechanisms in long-term planning; furthermore, it is necessary not only to focus on the technological capabilities needed to reach a desired future state, but also to align other capabilities through asset orchestration in areas such as organization, management, marketing, resources and risk models. Practical roadmapping has mainly been positioned within technology management and, more recently, technology prediction [4-6]. Additionally, technology management has recently been described as a dynamic capability, particularly when it is related to a management practice that appears to capture on-going technological changes effectively and dynamically and convert these changes into value [7].

There is a long tradition of wanting to foresee future technological developments. This desire has only become more pronounced with the increasing pace of technological development and the growing numbers of technology companies that focus on knowledge and technological development as important factors for ensuring sustained competitiveness. Technological foresight is different from technological forecasting, as the former includes the possibility of using participatory processes that involve various stakeholders in information gathering [8-10].

What is "roadmapping" according to the scientific literature? This term was originally used by Motorola in the 1970s [11]. Phaal, Farrukh, and Probert [12] define roadmapping as a strategic visualization that depicts the route and procedure required to navigate from the current situation to the desired future situation. Goenaga & Phaal [13] extend this definition by noting that roadmapping generally takes the form of a graphic representation that provides a high-level strategic view of the topic of interest, with support from appropriate documentation. The most flexible framework for roadmapping is typically a multilayered, time-based chart that incorporates various perspectives into a single visual diagram.

However, since Motorola popularized the term "technology roadmapping" in 1970, it has been applied to many other settings, although the notion still finds its widest application within the electronics industry [12]. Even within this context, however, technology roadmapping may be underutilized; a recent study of 800+ cases of foresight activities worldwide from 2002 to 2006 demonstrates that technology roadmapping was a less frequently used foresight tool (8.1%) [4], in

[8] One example relevant to pharmaceuticals is compliance, or the degree to which a patient correctly follows medical advice.

line with the aforementioned notions that organizations tend to choose the foresight methods that are most easily applicable and that at least some companies are reluctant to engage in technology roadmapping processes [14]. Furthermore, Popper's study from 2008 [4] shows that various types of organizations, including governmental agencies, research communities, companies, trade bodies/federations and non-government organizations (NGOs), all feature similar proportions of roadmapping use relative to the use of foresight activities as a whole.

A study of roadmapping activities across different industries showed that, of 934 roadmaps collected from 2005 and 2006, 5.1 and 4.0 percent originated from activities in the life science and healthcare industries, respectively [12]. In comparison, information technology (information, communication and software) was the subject of 22.6 percent of the analyzed roadmaps, indicating a lower application of roadmapping as a tool in biotech and pharmaceutical industry. Lichtenthaler's 2004 study [15] supports this finding. He analyzed technology management activities in 26 leading multinational companies within the pharmaceutical, electronics (telecommunication) and automobile industries and found that roadmapping was often used in electronics companies, only sometimes applied in pharmaceutical companies, and seldom used for technological development in the automobile industry.

Simple online searches (via Google™) for roadmapping activities in pharmaceutical and biotech contexts indicate that it is difficult to find examples of technology roadmapping by companies. Most of the accessible roadmaps originate from academic research or national-level initiatives. Of these, Canongia et. al (2004)'s foresight study on the applications of biotechnology in drug development [16] and The Canadian Biopharmaceutical Industry Technology Roadmap [17] are interesting examples of the application of foresight in the biotech and pharmaceutical industries.

However, these few examples highlight an important limitation of the above-mentioned studies, namely, that information regarding foresight activities may not be available in many industries due to the confidential nature of strategic planning within the corporate context. Given that, although confidentiality may have biased the results from these studies, the conclusion still appears to be that roadmapping is not widely used in life science industries. However, this conclusion may change in coming years as roadmapping becomes more established as a standardized approach to strategic planning.

The most common application of roadmapping is still the Motorola origin of roadmapping as a technique that lie in aligning technology development with product development. However, recent literature on roadmapping have extended the framework to include the technique of explorative roadmapping, that is as a tool and method for valuating early stage technology investment decisions [18] and for charting exploitation strategies for early stage technologies [19]. Such new applications could provide a decisive incentive that introduces technology roadmapping to a broader audience in the biotech and pharmaceutical industries [16].

It appears reasonable to ask how explorative roadmapping relates to the theory of dynamic capabilities. In 1996, Teece commented that innovation may be a quest into the unknown [1]. Although this observation may be true, resources can nonetheless be directed in a more efficient way, and a firm's ability to innovate can be enhanced, if that firm addresses the uncertainties of future events using a Schumpeterian view of innovative competition that features creative destruction of competencies or disruptive technologies. Dynamic capabilities denote certain routines or practices addressing the firm's ability to renew its resources and adapt to changes in the environment [20, 21]. Such capabilities therefore include the scaling up of the firm's ability to redirect resources to seize business opportunities. Allocation of resources is essential to direct resources into the most promising avenues while excluding less viable technologies. This redirection of resources can improve the firm's ability to react and adapt quickly to changes in the strategic environment.

Last but not least, the critical relationship between explorative roadmapping and commercialization issues should be addressed. The commercialization of technology refers to the process of determining when a technology is ready to be introduced to the market and implemented in a commercially viable product. This part of innovation may be overlooked in theory, but not in applied business practices. For companies to remain competitive, innovation and new technology should be means of introducing product features that differentiate one product from other available products. The value of this perspective lies in the distinction between technology and new products:

> *"A technology is essentially a "capability", often a versatile one that can be used in more than one product. Products are occasionally embodiments of this capability and mediate the process of bringing it to market and realizing value from it*" [22](Jolly, 1997, p. xv).

A commercialization strategy is therefore a company's focus on developing phases of a technology towards becoming a mature technology that is ready for market introduction, thus profiting from technological innovation. Commercialization can thus be regarded as the investment aspect of R&D; i.e., commercialization is a strategic perspective on an invention's early innovation phase. The stages of technology development typically begin with an exploratory phase focusing on ideas, followed by a funnel process in which a few selected ideas are matured and their paths toward market introduction are described, leading to the development of a commercialization strategy for the given technology. In the process, key stakeholders, goals and milestones are identified. Frequently, market surveys, customer analysis and customer involvement analysis are also included [23]. However, despite the broad array of analyses and idea maturation, very few technologies make it to the actual commercialization stage and are successfully introduced to markets [24][22]. Thus, bringing technologies to market and creating viable paths for such commercialization to occur are both valuable parts of the innovation phase.

5.1.1. Claim, research questions and case

The hypothesis that forms the basis of this study is therefore derived from these challenges.

In particular, we hypothesize that companies could improve their knowledge base by introducing a practical exploratory roadmap method to analyze and understand long-term trends and market drivers for early commercialization strategies. Especially, if aligned with an analysis of barriers and capabilities needed for successful commercialization.

We therefore claim that such an approach would enable them to make better decisions about whether a technology is suitable for commercialization if it is based on an analysis of what sort of capabilities that is needed for the technology to be commercialized. An analysis integrated with the roadmapping framework, and thereby providing a knowledge base dealing with the early, uncertain stages of technology, and provide a clearer picture of which potential types of commercialization would best suit the technology. Although strategies for the commercialization of technologies are an important driver in innovation systems, an applied model for explorative roadmapping integrated with dynamic capabilities does not yet exist.

Thus, the overall broader research question explored in this study asks: How a model for explorative roadmapping integrated with dynamic capability thinking could be applied in practice? Such a model could enable a company to have a systematic yet flexible framework that provides it with a strategic overview of its innovation capabilities, even for initiatives that are already in the pre-design phase.

The investigation presented in this work implements the theoretical notions discussed above in a real-world test case, thereby allowing a practical assessment of the use of strategic roadmapping for commercialization analysis. In particular, this study considers the case of Novozymes A/S, a large biotech company that is currently moving into the biopharmaceutical sector with a number of new products. Among these products is a novel drug delivery solution, a second-generation albumin fusion that was called *albufuse*$^{2.00}$ at the time that we were first introduced to it. The company has a long-term vision of creating a flexible drug delivery platform based upon this innovation.

5.1.2. Outline of article

Following this introduction, the underlying theory is presented and discussed in section 2, yielding a conceptual framework. In section 3 the developed methodology that was applied in the case study analysis, also called the project outline is presented and illustrated. Data gathering, and workshops were conducted between August 2010 and May 2011, and the concept was fitted during the initial phases of the case study analysis. The development of these methods are based on the argument that these methods must be developed in an applied context not only to capture the complexity of dealing with uncertainties, but to provide the novelty of how to customize the roadmapping process to specific time-relevant needs of the company and industry in question.

In section 4 the case study analysis is presented following the project outline as presented in section 3. Supportive tools and findings are a key outcome from the study as discussed in section 5. The roadmap and the capability maps both provide a visual overview and therefore valuable tools that illuminate possible paths and critical decision points in time to reach the vision, in this case, a drug development platform before 2020. The roadmap and capability maps were implemented in Novozymes' strategic practice, and are in this section discussed as a possible practice inspiring other managers and companies. Lessoned for academic are discussed as well in the last section including that participatory processes are not that straight forward.

5.2. Theoretical framing

The following review has a bipartite focus: we first explore the practical usage of roadmapping for the strategic planning of commercialization processes, then review technology roadmapping and dynamic capabilities in the biotech and pharmaceutical industries to provide background illustrating how this study provides new insights for both academia and this industry. The review section ends by illustrating the concept of roadmapping as a foresight tool and a carrier of information on various levels.

5.2.1. Technology roadmapping

Since Motorola popularized the term “technology roadmapping” in the late 1970s, the method has developed and gained popularity as a flexible way of analyzing and integrating technology management into business strategy and national-level policy-making [5,25-27]. Because roadmapping was initially developed in companies and organizations as a practical tool for technology management, a theoretical framework has only emerged within the last 10-15 years. Initiated by Baker and Smith’s study in 1995 [28], along with Galvin’s notion of *Science Roadmaps* from 1998 [29], technology roadmapping has begun to be explored not only as a practical tool, but also as an established practice that can be addressed through academic research.

Several researchers argue that this evolution of the academic study of roadmapping has led to the lack of a defined theoretical methodology, which makes roadmapping a vaguely defined term covering a broad field of technology management and foresight disciplines [25]. This appears to be the reason that definitions of roadmapping terminology and processes tend to differ in the literature. Despite these differences, however, researchers agree on the fundamental objectives and general structure of technology roadmapping.

This fundamental consensus can be noted by considering the complementary nature of the following three central definitions of a technology roadmap:

- Barker and Smith (1995) [28] define technology roadmaps as "…part of the technology management toolbox as a high-level tool for planning the innovation process, service application, and researches in connection with identifying drivers at market and efforts of duplications."
- Phaal, Farrukh and Probert (2009) [12] define technology roadmaps as "…a visualization of the research strategy, showing the route and navigation from the current situation to the

desired future." Moreover, they state that "…the effectiveness is on the understanding of firms' internal use and establishing technological capabilities in linking technological resources, organizational objectives and the changing environment."

- Goennaga & Phaael (2009) [13] state that "…roadmaps generally take the form of a graphic representation that provides a high-level strategic view of the topic of interest, supported by appropriate documentation. The most flexible framework comprises a multilayered time-base chart, bringing together various perspectives into a single visual diagram."

Technology roadmapping, then, is essentially a foresight tool because it seeks to translate projections of future development into applications for present-day decision-making [28]. This relation is highlighted by the three main questions that a roadmap user seeks to answer (modified from Phaal and Muller (2009) [26] and Bruce and Fine (2004) [30]):

- Where are we (the company) now?
- Where do we (the company) want to go (with this technology)?
- How can we (the company) get there?

One of the main characteristics of the technology roadmap is that it allows for the mapping of the environment surrounding a given technology and for the proposed evolution of technology and product development. These aspects of development are put into a timeframe along with identification of other strategic issues, such as resource needs. The methods thus allow for a structured analysis of the context in which a technological evolution occurs, allowing organizations to understand and communicate their technological development and long-term strategic planning [31]. Although researchers have studied various generic types of roadmaps, as described by Breeton, Phaal and Probert [5] and Bruce and Fine (2004) [30], we chose to make a simple distinction between just two broad categories of roadmaps, one of which naturally facilitates the creation of the other:

Strategic landscape – This type of roadmap is more exploratory in character, as it surveys future possibilities. In these roadmaps, as explained in Loveridge (2002) [32], the STEEPV acronym for the six themes of thinking about the future – Social, Technology, Economics, Ecology,[9] Political and Values – guides the search for uncertainties.

Technology roadmap – This type of roadmap is more goal-oriented, with the purpose of defining strategies to realize clearly delineated future targets. The timeframe is important, as are the alignment of technology, products and optimization plans with market requirements and appropriate timing.

The strategic landscape model raises the question of what socioeconomic factors might influence forthcoming market conditions and provides an overview of such factors, thus shaping the strategic perspective of a firm. Strategic landscapes can be generated using opinions gleaned from participatory workshops, interviews or expert panels to make estimates of the most important trends and of the likelihoods of various possibilities occurring. The strategic landscape can then serve as a backdrop for the extension of foresight analysis into technology roadmapping. These foresight tools can thus synergistically serve to address the question of what technological developments and product features are required to deliver a product that becomes a viable commercial offering in the future.

Technology roadmaps consist of different layers of information fitted into a defined timeframe, as seen in figure 2.1. The typical layers of roadmaps include, but are not restricted to, the market and business trends that create a specific need for new product features, the features of a product and/or service that are a response to the external requirements and the technological innovations needed to develop these product features. Further information on the resources needed to develop the product features, such as economic resources and organization, is also often included. These layers of information are then presented in relation to each other, thus providing an overview of the developmental process as an entity in which both technology and product evolution are aligned with market needs. Typically, the condensed information presented in each layer of the roadmap is collected and analyzed based on different foresight methods and participative processes involving stakeholders in the technological development [33][5,30]. Through such processes, the key information relating to development of the given technology is identified and can be connected to related risks and uncertainties. By developing roadmaps using participative processes, the framework can play an essential role in ensuring stakeholders' involvement on many levels and

[9] What Loveridge (2002) [32] calls the second E (Ecology) is often misinterpreted as the environment, but ecology means the relation between an organism and its environment – here, e.g., the firm and its strategic environment.

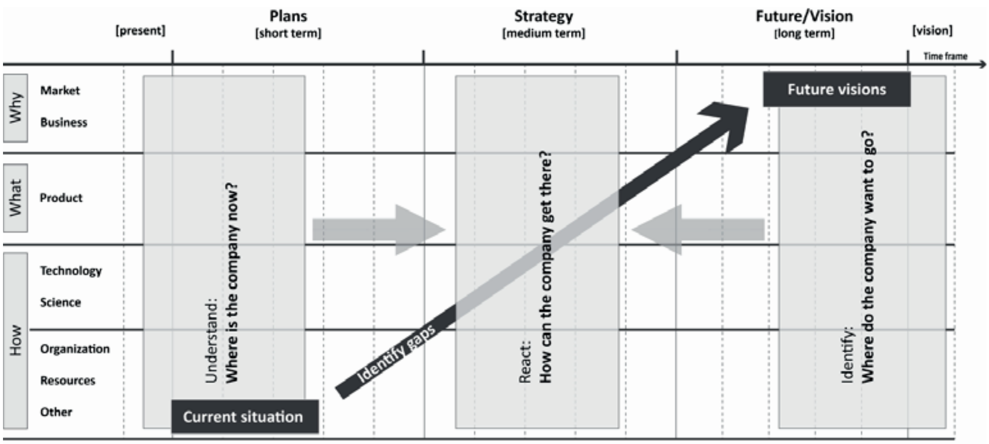
concurrently aid in creating a common understanding of strategic planning initiatives and goals [26].

The timeframe of the roadmap, the level of detail, and the layers to be included depend on the purpose of the roadmap and the context for which it is being developed. Technology roadmaps are thus extremely flexible tools that can be used as frameworks for most technology management and strategic planning relationships in companies. Examples of technology roadmapping applications in business settings, adapted from Farruckh et al. (2003) [34], can include the following:

- Product planning is the most widely used roadmap type. It includes a focus on product evolution and the technologies needed for developing different generations of products.
- Strategic planning is a less operational roadmap compared with product planning; on the business level, it serves to identify visions and improve evaluation of opportunities, threats and risks. It generally includes the layers presented in figure 4.1.
- Integration planning focuses on the interplay between technologies in a system; for instance, the integration of multiple existing technologies to form a new technology.

Although roadmaps are flexible and can take many forms, the most general framework is a graphic mapping of information layers into the defined timeframe, as outlined in the following figure.

Figure 2.1. Outline of a strategic roadmap framework



Source: Adapted from Phaal (2009)[12]; Phaal and Muller (2009)[26]; and Ricard (2010) [35].

The general composition of roadmaps consists of a visual presentation of layers of information relating to the development of a technology in a given context. These layers are presented to the right in the figure and are separated into three groups. The '*Why'* are the external trends that essentially create the purpose of the roadmap, i.e., the market pull for a technology. The '*What'* covers the tangible features of products and services that need to be created to meet the market requirements. The '*How'* group consists of the resources needed to develop the products, i.e., the technology, science and skills, along with the internal context needed for development of the technology, such as organization, economic resources and facilities. By mapping these layers into a timeframe, it becomes possible for an organization to understand the current situation of *where it is now* and identify its visions of *where it wants to go.* The benefit of roadmapping is consequently that the organization can now identify knowledge gaps that exist regarding achievement of the future vision and then react by addressing these through strategy and technology management. The focus on condensing complex information into a one-page graphic framework is a key benefit of technology roadmaps as it allows for top-level visualization of the association between *market pull* and *technology push*. Roadmapping is therefore a powerful communication tool providing benefits such as an improved common understanding of complex information among different stakeholders and a platform for knowledge sharing [26]. Furthermore, Barker and Smith [28] argued in 1995 that visualization of roadmaps can also aid in verifying the consistency of collected information and data.

Phaal and Muller (2009) [26] recently described technology roadmaps in corporate settings as a "strategic lens" due to their ability to help companies view and communicate technological development in terms of market needs and business perspectives. This description further highlights the close relationship that exists between roadmapping and technology management as roadmapping is often used to create strategic dialogue between stakeholders and thereby support technology management and long-term business planning. Recently, the roadmapping framework has been extended to applications for purposes such as product development and the identification of new business opportunities, as noted by Lee et al. (2009) [25]. Such applications could provide a strong incentive to introduce technology roadmapping to a broader audience for strategic planning purposes.

Although technology roadmapping is a flexible platform, scholars have identified a number of obstacles to the ongoing success of roadmapping in business settings. Several of these are related to the obstacles that have been identified for foresight methods in general ([14]), whereas others specifically relate to the roadmapping process in particular. Three key challenges are summarized here:

- Roadmapping is not a "magic bullet". Roadmapping is not a stand-alone methodology, but merely a flexible framework. Thus, companies must not believe that roadmapping can solve every challenge in long-term planning; rather, they must understand that roadmapping is a learning process that usually produces more questions than answers [36,37].
- Roadmapping must be tailored to be applied productively. Researchers generally emphasize that, due to its flexibility, roadmapping needs to be customized to the specific current needs of the company in question. This demand often leaves companies confused and thus reluctant to engage in roadmapping processes [26,33].
- Roadmaps must be kept "alive". The optimal roadmap should evolve and be an ongoing process; thus, the challenge is to keep updating and developing the map in response to changes [37].

5.2.2. Dynamic capabilities approach

A dynamic capabilities approach explores the resources needed to profit from innovations, with a focus on not merely gaining from a single invention, but rather sustaining and developing competitive advantages over time. The approach has deep roots in evolutionary economics and Schumpeter's idea of creative destruction. It also relies upon the notion that new knowledge can create new opportunities and on Kirzner's related idea about the entrepreneurial skills required to sense new opportunities by taking advantage of existing information [38]. These theories describe two forces that are important to the dynamic capabilities approach, namely, creative destruction and the restoration of equilibrium [38]. The dynamic capabilities framework highlights that both the companies' resources (capabilities, assets, opportunities) and the ways in which a company accumulates and develops its resources are important for competitive advantage [39]. To put it simply, the dynamic capability approach takes a broader view of the *profiting from technological innovation* framework to understand the capabilities a company would require in the future and translates this knowledge into processes designed to achieve competitive advantage over time. The framework is a strong break from Porter's five forces, in which strategy formulation is focused on coping with competition, as the dynamic capabilities framework is focused on shaping competition itself. Its strategy formulation involves:

> *…selecting and developing technologies and business models that build competitive advantage through assembling and orchestrating difficult-to-replicate assets, thereby shaping competition itself* [38] (p. 1325).

In 1997, Teece et al. [40] defined dynamic capabilities with the following statement, referring to the definition promulgated by Leonard-Barton in 1992 [41]:

> *We define dynamic capabilities as the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments. Dynamic capabilities thus reflect an organization's ability to achieve new and innovative forms of competitive advantage given path dependencies and market positions (p.516).*

In the purest sense of the word, the term *dynamic* refers to a company's ability to shape and renew itself in response to changes in the market environment. The term *capabilities*, on the other hand, relates to assets, resources and competences. These must be developed dynamically to meet the requirements of the changes that occur in the market environment [40]. Thus, it can be stated that *dynamic capabilities* are future-oriented processes, whereas capabilities (assets, resources and competences) are static and relate to competitive advantages in the present [42] in the same way that complementary assets relate to present commercialization in *profiting from technological innovation* [43]. A company needs *dynamic capabilities* to change its present capabilities (assets, resources and competences) and adapt to the future.

The key mindset of dynamic capabilities theory is that a superior technology is rarely enough to sustain competitive advantage in the market. As noted by Barney et al. (2000) [20], a large body of research in the strategic management field from the 1990s focuses on knowledge and competitive advantage:

> *Much of this literature focuses on the role of dynamic capabilities, that is, specific processes firms use to alter their resource base, as sources of competitive advantage* [20] (p.630).

The companies that will stay competitive are those that foresee development in the market and act upon it using dynamic capabilities. The dynamic capabilities approach, as summarized by Teece in his paper from 2006 [38] and rephrased slightly by Augier and Teece in 2009 [44], deals with three separate types of processes that a company must be able to perform:

- Sensing
- Seizing
- Reconfiguring

Sensing deals with the ability to understand what will come, whereas *seizing* relates to the framework for *profiting from technology innovation,* i.e., for fulfilling the entire potential of the current situation. The term *reconfiguring* is the key to dynamic capabilities because it relates to the processes needed to change the resource base of the company to adjust to upcoming conditions. By employing this understanding, a company will sustain competitive advantage if it is able to *sense* the future, *reconfigure* its resources to *seize* the moment fully, and thereby realize the full potential of its innovations. In addition, the dynamic capabilities approach incorporates learning as a central element but also acknowledges the irreversible nature of certain processes in that a company's ability to change relates to path dependency. The direction that a company can choose depends on the path ahead *and* its current position, which is in turn shaped by its history (the path it has followed until now)[40]. As reformulated by Augier and Teece in 2009 [44], slightly modified from the Teece et al. (2007) [40] version, dynamic capabilities are*:*

> *The ability to sense and then seize new opportunities, and to reconfigure and protect knowledge assets, competencies, and complementary assets with the aim of achieving a sustained competitive advantage (p.412).*

In summary, dynamic capabilities deal with the processes that allow companies to sustain competitive advantages in fast-moving technological environments, given their history and current stage of development. Dynamic capabilities are therefore distinctive processes that facilitate not only the ability to recognize technological changes in the market environment, but also the processes of changing and shaping the company's asset positions in response to change. Although the foundations of dynamic capabilities approaches are well established, Ambrosini and Bowman [42] recently argued that further academic studies in the field are needed. In particular, they noted that scholars should pursue the possibility of linking dynamic capabilities to related fields of study and that case studies should be performed to identify and understand the nature of dynamic capabilities within specific industries. Is it, for instance, the existence of a given asset type or the methods employed to foresee future development that is more important for generating competitive advantages? Research has further highlighted the need to clarify certain concepts of dynamic capabilities that are frequently subject to different interpretations [42]. For instance, as Stieglitz and Heine recently argued, complementarity is seldom clearly defined, although it is a key element in the dynamic capabilities framework [45].

5.2.3. Technological experience

A number of case studies focus on dynamic capabilities and the importance of complementary assets in the biotech, pharmaceutical and biopharmaceutical industries. Rothaermel (2001) [46] links partnerships between small biotech (biopharma) companies and established pharmaceutical companies to the concept of complementary assets: New biotech companies are better than established companies at developing innovative technologies but lack the complementary assets needed to successfully commercialize their innovations. Biotech companies therefore form collaborative partnerships with established companies that have access to the necessary assets, e.g., manufacturing, supply chain and established marketing capabilities [46]. The approach of Rothaermel's study was to collect data and build mathematical models to test the relations between various parameters in these partnerships. The premises of the dynamic capabilities framework were used to develop a model in which independent variables were included to reflect various capabilities. Such methods allow for assessments of the importance of different capabilities relative to the success criteria established in the study. Similar types of modeling studies were conducted by Deeds et al. (1999) [47] to provide an analysis of product development capabilities in new biotech firms. After testing a number of parameters, those researchers found that the geographic location and scientific knowledge in the company (as given by the expertise level of employees) are important for product development. A more recent study by Nerkar and Roberts (2004) [48] uses the same approach to study the success of product introductions in the pharmaceutical industry based on technological and specific market experience. In accordance with the findings of Teece's studies (1986) [43], they found that specific technological experience is the most important parameter for the success of innovations. Indirect technological experience within an area related to the innovation in question, on the other hand, was found to be important only if indirect product-to-market experience followed. This finding suggests that companies can innovate outside of their core therapeutic area and benefit from previous technological experience if they have a generally strong product-to-market orientation [48]. Although such studies are not directly implementable for this particular project, they introduce examples of dynamic capabilities evaluations within relevant industries. Furthermore, the classification of market and technological experience based on how distant that experience is from the innovation in question provides an interesting perspective [48].

5.2.4. Building the conceptual model

It was established in the theoretical framework that technology management focuses on the development of technological capabilities, whereas the dynamic capabilities framework covers capability types in a much broader sense. As this study aims at analyzing commercialization strategies, the connection between technology management and capabilities form the basis for addressing roadmapping from a dynamic capabilities perspective.

We argue that technology roadmapping can be chosen as a conceptual framework for long-term strategic planning of specific technologies, their application and potential markets due to its flexibility and the power of its application as a communication tool. The link that we create between roadmapping method and the dynamic capabilities perspective is the complementary asset identification method. Based on this connection, capabilities and assets for successful commercialization of the present-day product offering are identified through participatory processes by firstly, expert interviews, secondly, a project workshop initiated by the business development group, and thirdly, guided interviews to identify and rate the complimentary assets needed for commercialization.

The capability identification process itself proved valuable as it contributed to the detection of risks for short-term development. Furthermore, the process, by identifying capability deficiencies in certain areas, proved that the company's path dependency is a challenge for new path creation as it relates to the technological development of a pharmaceutical drug delivery platform. The identified capabilities subsequently serve as the input for the roadmap, thereby introducing not only technological capabilities, but also capabilities in a much broader sense, into the roadmap. However, although the applied model was successful and helped to build an understanding of capability needs for future development, the process presented here was merely a simple implementation combining dynamic capabilities and technology management. Nonetheless, the study has helped to develop new visualization tools, such as complimentary asset method in the "capability maps", and furthermore demonstrates that such visualizations are important, along with the underlying structure of the conceptual framework involved and its participatory elements.

The strength of the explorative roadmapping approach is the market pull focus as it starts by identifying trends and market needs in the long run and then relates this information to new business opportunities, product features and R&D. Thus, the strategy focus integrates market pull, sensing and seizing future business opportunities.

Asset and capability identification, as presented in the following, relate primarily to short-term development and hence to Teece's identification of the importance of complementary assets for profit from innovations [40]. In particular, Teece proposed that gaining an understanding of complementary assets in the present can provide an add-on to the company's strategy in understanding its path dependency and identifying the dynamic capabilities needed for long-term strategy planning.

Such identifications were made through the interviews and workshop. Following an identification process, interviewees were asked to rank or valuate the capabilities in relation to both their importance for commercialization and the company's access to the given capability. The following evaluation scheme used in the case study of Novozymes, which we call a capability map, is adapted from the complementary asset mapping presented by Teece (1986, pp. 297) [43].

Figure 5.3.3.1 Graphic representation of a capability map

The capability map introduces a graphic framework for mapping capabilities into four groups based on whether those capabilities are key or unimportant and on the degree of major or minor company involvement with those capabilities. A capability can thus be placed into one of these groups according to its importance for success (horizontal) and the extent to which the company has access to the capability (vertical). The placement of capabilities into the groups presented should lead to different reactions:

Group 1 is the most important group: these capabilities are important for success, but the company does not at present have access to them. Complementary assets and capabilities placed in this group must be considered in terms of the timeframe in which they are required and the method by which the company can subsequently secure access to them. The possibilities for such methods consist of *internal development*, *contracting* access to the capability, *partnering* with other companies that have the capability or *internalizing* the capability by acquiring it from other companies or hiring employees with the needed skills or expertise.

Capabilities that fit into group 2 are likewise important for success, but these are capabilities to which the company presently has access. They are therefore the value-generating capabilities in the system. A strong internal focus on group 2 capabilities must be sustained to ensure successful commercialization.

Group 3 capabilities, on the other hand, are of low importance for commercialization, and the company does not have access to them. Because these capabilities are of only minimal import, the company's lack of access to them should not merit any significant action.

Group 4 capabilities are likewise unimportant for commercialization success, but the company has access to these capabilities. Capabilities and assets in this group must be analyzed because they should only be sustained if they are value generators for future projects. If Group 4 capabilities are not projected to generate value through other means, the company may wish to eliminate these assets and capabilities to achieve cost reduction.

The framework for capability identification can serve as an add-on to roadmapping processes, providing managers and decision-makers with systematic methods to sense and seize the need for complementary assets in time to respond to changes in the strategic environment and thus guide them in asset orchestration. By linking asset identification to strategic planning, the company can increase the possibility that it has access to the right specialized complementary assets at the right time to ensure successful commercialization of products following any required innovations at each step of the technological development.

Novozymes' core operations are centered on its enzyme business and industrial biotechnology expertise, and only within the last six years has the company entered into the biopharmaceutical industry via acquisitions of established biopharmaceutical companies. Based on the theories of capabilities and needs presented by Teece in 1986 [9], the success of an innovation is largely determined by whether the innovating companies have access to the right capabilities and assets. Analyzing the company's complementary assets for Albufuse® Flex is therefore regarded as important to understand opportunities and threats for commercialization of the Albufuse® Flex technology.

Roadmapping as a framework can be applied to systematize information collected for each of the different layers of information. Reviewing the foresight literature, we found a method somewhat similar to what is called the "roadmapping mix" illustrated in Popper (2008) [4]. A version of Popper's roadmapping mix is presented below.

Figure 5.2.4.1 illustrating the roadmapping mix in Poppers diamond

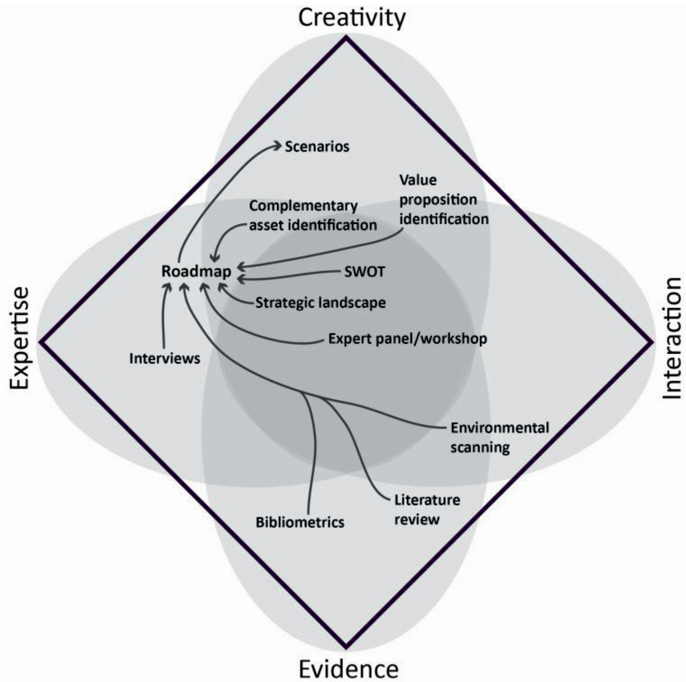


Figure 5.2.4.1 presents the methods that can be employed to obtain the information, and mapped into the Popper's foresight diamond, which is organized according to each method's capabilities,

namely, whether the information acquired with the given method is based on *evidence*, *expertise*, *interaction* or *creativity.* As illustrated in the figure using the Popper version of the roadmap mix, we did try to map our methods into the diamond using these categories for the data and information gathering in the roadmap process, but in this particular research, the application of the Popper diamond is proven to be unfit, as we would argue that the position of these methods varies depending on how they are implemented. The purpose of the Popper diamond therefore only serves as inspiration in the Albufuse® Flex project using various *foresight* methods.

We then claim that the idea of combining various methods lies in a process moving from an initial understanding of the circumstances: what is the problem and what methods are possible prior to collecting data and information, and initially interpretation of findings. Methods used are therefore related to three project phases;

1) initial understanding
2) collecting data & information,
3) and interpretation

Thus the initial understanding (phase one) is related to the architecture of the roadmap (phase two), layers of information and methods possible for gathering data and information, and eventually interpreted and analyzed using the roadmap framework (Phase three) – a somewhat iterate process when keeping the roadmap *alive* (an ongoing process).

5.3. Case study analysis

This following project is presented in chronological order of the three phases of the case study analysis. The first phase was to acquire an initial understanding of the promising emerging field of biopharmaceuticals along with delivery of biological based medicines. Novozymes is considering entering this field as a fairly new niche player, relying on its biotechnical capabilities and experience to expand into other business areas with high growth potential to ensure long-term business opportunities outside of the enzyme business in which it has traditionally specialized. One of the initial steps was to collect data and information to understand the strategic landscape of Albufuse® Flex and identify the complementary assets needed to achieve its successful commercialization. This information was gathered through expert panels and workshops, which comprised the second major phase of the case study. The third and final phase was the interpretation and analysis of data and information, which led to the development and execution of the roadmap.

5.3.1. Phase 1: Initial understanding and overview of case

In the pharmaceutical industry, biopharmaceutical research is a promising and emerging field. Biopharmaceuticals are defined as biologically based pharmaceuticals produced using biotechnology. This class of pharmaceuticals includes protein and peptide drugs, such as insulin and growth factors, along with antibody-based therapeutics. This field also includes many vaccines and novel nucleic-acid-based drug candidates.

Over the last 20 years, the range of available biopharmaceuticals has steadily increased, and Evers in 2010 [49] predicted that the overall market for biopharmaceuticals will continue its rapid growth over the years to come, in contrast to the market for small-molecule drugs, which is stagnating. The market for small-molecule drugs is challenged by increased cost, longer development time, generic drug entrance and decline of novel discoveries. The recent advances in biotech provides new possibilities for novel discoveries which is now changing the pharmaceutical landscape, and most 'big pharma' companies today have biopharmaceuticals in their pipelines [49]. Indeed, the pharmaceutical industry as a whole is changing, in part due to increased governmental focus on the cost-effectiveness of drugs and the life cycles of diseases, e.g., curing maladies instead of simply treating them. The challenges and also new opportunities in the pharmaceutical industry have resulted in increasing numbers of partnerships between firms and outsourcing of R&D and have transformed the system of generating pharmaceutical innovation by introducing new players, such as contract research organizations (CROs), contract manufacturing organizations (CMOs) and small research-intensive companies (usually small start-ups and spin-offs from university research).

Although biopharmaceuticals are changing the landscape of drug development, the process of biopharmaceutical development is just as complex as that of small molecule drug development, with new biopharmaceutical compound research typically requiring high risks, long development times and an intensive regulatory approval process before reaching the market[10]. Despite the

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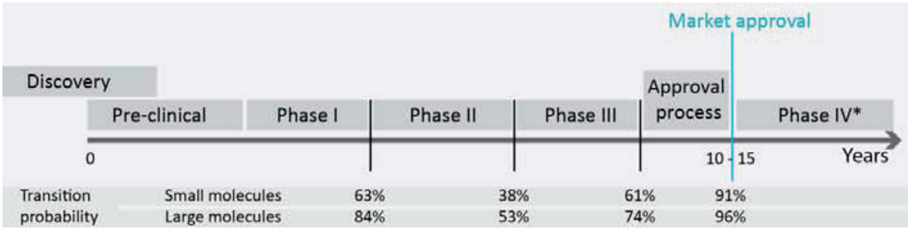
[10] The average price of developing a drug from idea to market is 1.24 billion and 1.31 billion in 2005 dollars for biopharmaceuticals and small-molecule drugs, respectively [51]. Moreover, just above one third of the R&D costs in pharmaceutical development are spent before phase II, at which point the drug's probability of reaching the market is less than 10%.

aforementioned challenges, drug development is an immensely competitive industry driven by the possibility of extremely high returns on investment (ROI) if a drug candidate reaches the market [50].

Figure 5.3.1.1. Pharmaceutical development and approval process



*Phase IV is also known as a post-marketing surveillance trial.

Among the differentiating characteristics of developments in the pharmaceutical industry are the defined regulatory phases, which are presented in figure 5.3.1.1 The pre-clinical phase involves animal testing to obtain preliminary data on the pharmacokinetics, efficacy, bioavailability and toxicity of the potential drug. After preclinical analysis, a drug candidate submission is delivered to regulatory authorities, which can approve the putative drug for studies in humans.

Phase I typically involve administering the drug to 10 to 200 healthy volunteers and focuses on analyzing drug safety. Phase II trials involve larger groups of volunteers (20 - 300), and the subsequent phase III studies involve multicenter tests on large patient groups (200 – 3,000) to analyze the effect of the drug. Phase III studies are typically the most time-consuming and expensive stage of the drug approval process [51].

The drug candidate may produce unacceptable results at any of these phases, which will result in discontinuation of the development process. The transitional probability for moving from one phase to the next incorporates this risk and can be calculated by analyzing the development of a drug pipeline over a period of time. A recent study based on drug candidates that entered clinical trials from 1993 to 2004 is shown in figure 5.3.1.1, with results for both small molecules and large-molecule biopharmaceuticals. As has been critically described in the literature by Dimasi et al. [51,52], the current rate of new innovation is slow, and the costs of clinical trials from the preclinical phase to phase III are growing at an almost exponential rate.

Such developments underline the need to optimize and improve commercialization strategies that integrate long-term planning to meet these challenges and ensure successful commercialization, which is needed to sustain the company's competitive advantages over time.

In an exclusive interview Senior Director of Novozymes Biopharma, Svend Licht who is directly responsible for the commercialization of technologies, emphasized that Novozymes looks at trends in the surrounding environment and identifies the technologies for which they want to pursue commercialization based on those trends. He emphasized the need to stay competitive by developing products of improved quality at a lower price, along with possibly pushing technologies through pharmaceutical quality testing process at a higher pace. This statement captures the essence of the strategic challenge: to deliver technological solution at a faster pace for lower cost, yet at the same time keep improving on the quality, thus key words being: cost, quality and time.

5.3.1.1. Novozymes and the Albufuse® Flex project

Novozymes is a publicly traded biotechnology company with revenues of 9,7 billion DKK (2010). The sale of industrial enzymes, the company's major specialization, accounts for more than 93% of these revenues [1]. In fact, the company is the world's largest producer of enzymes for industrial applications, with an estimated market share of 47%. The main value chain in Novozymes is therefore dependent on business-to-business sales of biologically produced enzymes and microorganisms. Novozymes has always strived to be a technologically oriented growth company, and the company therefore reinvests 14% of its revenue into R&D, with a stated ambition of 10% yearly growth [53]. In addition, Novozymes works with a triple bottom line and therefore places special emphasis on Corporate Social Responsibility (CSR), with particular emphasis on the delivery of sustainable solutions to customers.

Novozymes is headquartered in Denmark, where approximately half of its employees (44%) are located. The rest of its 5300 employees are scattered in 30 countries around the world, with primary concentrations in Europe, the US, China, India and Brazil [53]. Although Novozymes only recently celebrated its 10-year anniversary (November 12, 2010), its core operations are derived from a business line that has been in operation since 1940, when the company Novo Industry, which originally centered around insulin production, decided to expand its business into industrial enzyme production. Novo Industry merged with Nordisk Gentofte in 1989 and thereby became Novo Nordisk, which was, at that time, the world's leading producer of insulin and detergent enzymes.

The new company focused on continuous development of pharmaceutical products; refinement of insulin, growth factor and homeostasis therapies; and expansion of the industrial enzyme business. Novo Nordisk split into three separate companies in 2000: Novo Nordisk A/S (pharmaceutical products), Novozymes A/S (industrial biotech, focused on enzymes) and Novo A/S (a holding company wholly owned by the Novo Nordisk Foundation).

Figure 5.3.1.2. Novozymes' management system and organization

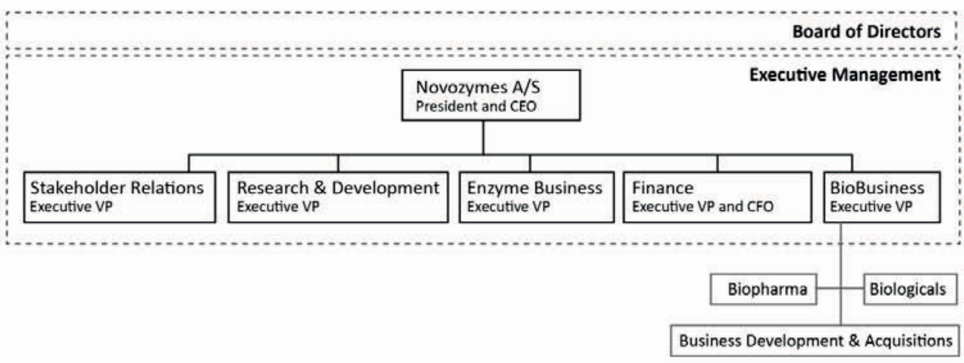


Figure 5.3.1.2 shows the two-tiered management system employed in Novozymes, with both executive management and a board of directors. The figure further shows the areas of the department called BioBusiness, the category under which Novozymes Biopharma is organized. The company's enzyme business (the bulk of the rest of the company) is subdivided by industry, underscoring Novozymes' strong focus on customer segments. The company's structure largely features independently functional units, but with certain cross-functional matrix elements, such as those evidenced by collaborations between business development, R&D and sales and marketing.

Although Novozymes' enzyme business has experienced good growth, the company decided in 2001 to utilize its biotechnological expertise and experience to expand into other business areas in an attempt to ensure long-term business opportunities in areas of high growth potential beyond enzymes alone. Since 2007, these non-enzyme opportunities (collected in a division called BioBusiness) have been focused on the two main areas of biopharmaceutical and biological development. There is a strong focus on growth in these areas, and the company's objective is for BioBusiness to develop into a 6 billion DKK business by 2018.

Novozymes Biopharma is a sub-supplier of ingredients for the pharmaceutical industry. Today, Novozymes is a niche player in the pharmaceutical industry. They see themselves as differentiated from their competitors through the delivery of high-quality recombinant products and technological solutions. The company's plans for continued growth and development in this sector are predicated on utilizing expertise from enzyme production and the development of solutions that focus on end goals, i.e., solutions that can quickly be scaled up to full-scale production. The company additionally focuses on delivering animal-free solutions, including an understanding of the importance of sustainability in each step of its development and operations.

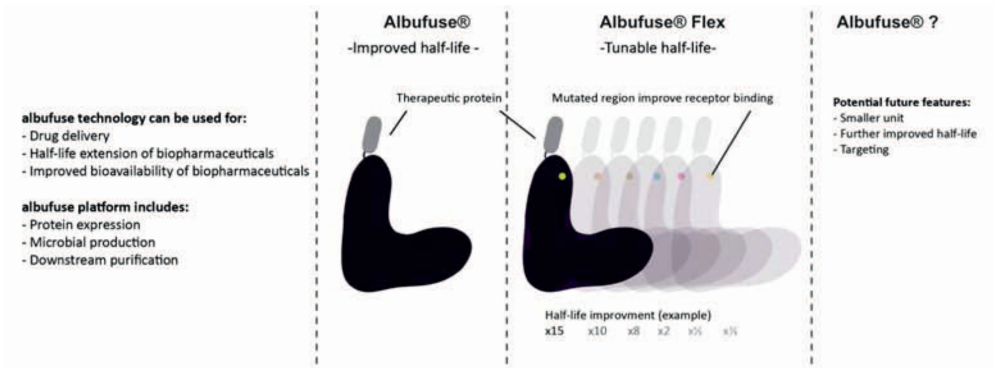
The strategic focus for Novozymes Biopharma, as defined in 2010, is on two main technologies, *albumin* and *hyaluronic acid*. Albumin is used in drug, vaccine and device manufacturing, and recombinant hyaluronic acid is used for biomedical applications. In summer 2011, Novozymes will open a new factory in China for the production of hyaluronic acid, which will underscore the company's position as the market leader for recombinant hyaluronic acid. The company also states that they are the market leader for albumin, although this position might not be sufficiently communicated to the market as a whole (low brand awareness) [54].

A major thrust of Novozymes' initiatives is a second-generation product for drug delivery, which is organizationally placed in the biopharmaceutical division known as Novozymes Biopharma.

Novozymes' expertise and experience with albumin have made it possible for them to expand their development efforts regarding this technology. In particular, the context underlying this analysis is the development of technologies for drug delivery based on albumin, the Albufuse® Flex technology. With this new proprietary technology, it is possible to genetically fuse native human albumin to biopharmaceuticals, thereby creating a protein fusion entity that enables extension of a drug's half-life and improves the bioavailability of the drug. Both of these effects are currently in great demand in the biopharmaceutical industry. The albufuse technology fits with Novozymes' overall growth strategy as it is based on existing expertise and is considered a long-term financial investment.

The first Albufuse® Flex patent was filed in November 2010, with proof-of-concept studies being undertaken in the same year, concurrently with the filing of further patents; the actual commercialization of the technology was scheduled for 2011. The short-term business aim, and an immediate internal requirement for the project, is to secure a partner/customer for the development of drug candidates in 2011. The long-term vision for the company regarding the Albufuse® Flex technology is to create a fully flexible drug-delivery platform that can address every delivery challenge faced by the biopharmaceutical industry. With the second-generation version of albufuse, the Albufuse® Flex, altered versions of albumin should be used, thereby allowing for longer and possibly more controllable drug half-lives. A brief description of the technology, which is in focus, is presented in figure 5.3.1.3.

Figure 5.3.1.3 The Albufuse® Flex technology



Albufuse technology is based on native human serum albumin onto which a therapeutic protein is genetically fused, thus creating a new entity with the therapeutic effects of the drug and the molecular benefits of albumin. The Albufuse® Flex is based on albumin with point mutations that change binding to a key receptor, thereby allowing for a range of albumins with different binding affinities, which are hypothesized to demonstrate different half-lives. This is illustrated in figure 5.3.1.3. In production, only the specifically chosen molecules (e.g., molecules with at least 10-fold improvement in the desired binding characteristics) would be produced. Following the development and proof of concept of the Albufuse® Flex technology, a number of future improvements are under investigation. The same technology can also potentially be used for non-genetic conjugation and may thus be employed for drug delivery of small molecule drugs.

5.3.1.2. Current business model

The current business model utilized to commercialize the albufuse technology is based on licensing. Companies with biopharmaceutical drug candidates could license the Albufuse® Flex technology (IP and expertise) and thereby produce albumin fusions of their drug candidates. As albumin fusions are novel molecular entities, an actual albufuse product needs to go through all steps of the pharmaceutical approval process. The Albufuse® Flex technology could also be licensed for conjugation instead of fusion, enabling other regulatory approval processes. The value generated from the licensing process is therefore based on milestone payments from each development step until market approval. The strategy for Novozymes is to market the albufuse technology as a packaged platform solution for drug development along with complementary technologies offered by the company, such as the proprietary expression platform (yeast: *Saccharomyces cerevisiae*), downstream processing matrices and CMO capabilities. These features will not be explicitly discussed, but they are included in the analysis of product attributes and the company's complementary assets.

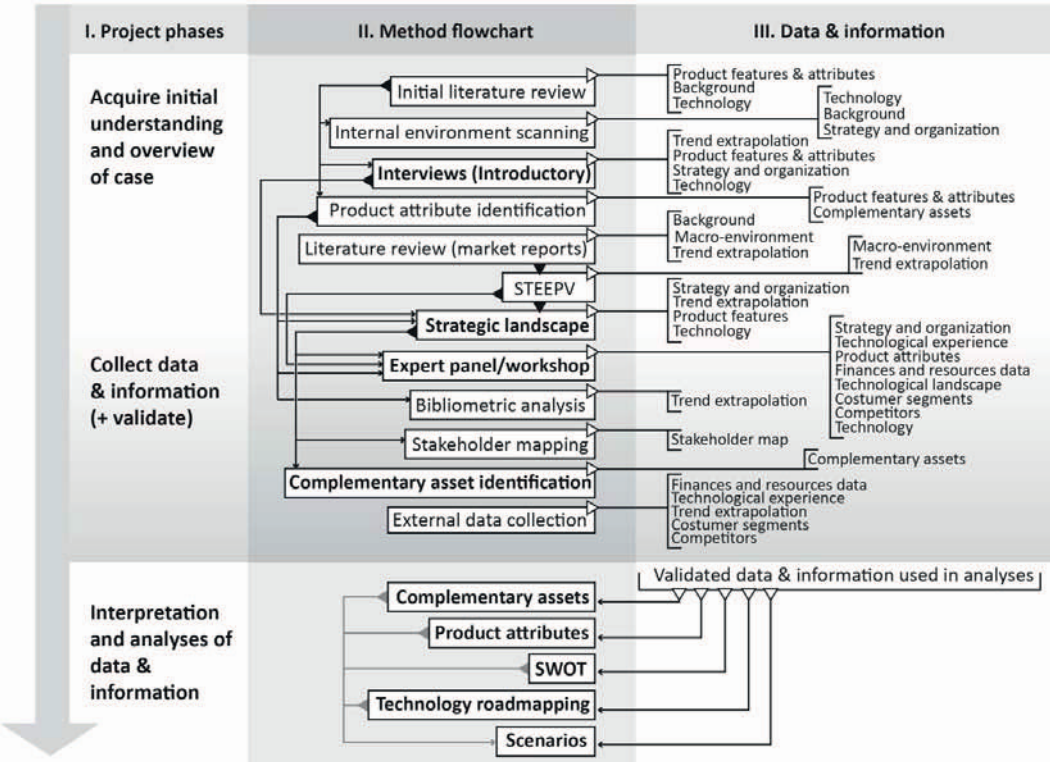
5.3.2. Phase 2: Collect data and information

Information for a study of this type can be collected using numerous methods and tools. In this paper, we chose to focus upon the methods that were important to the roadmap and scenario development of the presented case. The investigation as a whole obviously included further studies, such as an extensive literature review and environmental scanning, but the presented methods are those that offered key contributions to the study. The overall project is outlined in figure 5.3.2.1.

5.3.2.2. Project outline

Several foresight methods were employed to identify dynamic changes in the sociotechnical environment around Novozymes and the drug-delivery platform in question. Detailed information and knowledge were acquired through the analysis of each layer of information in the roadmap. The most important details were condensed into the roadmap, ensuring that the roadmap provided information on many levels.

Figure 5.3.2.1. Outline of the project



The chart illustrates the flow of methods for the study and approaches to data collection:

Column I describes the three main processes in the research design. Column II depicts the methodology flowchart. Filled triangles indicate main associations between methods; for instance, the use of details from the business plan (initial literature review) in product attribute identification can be observed. Column II also relates each method to the information and data acquired (and illustrated in column II), as indicated by open triangles.

Methods and data:

Interviews

Interviews were conducted as a key part of the early study and were largely focused upon three main issues: respondents' project expectations, important product features, and identification of obstacles to commercialization, which permitted the mapping of complementary assets.

Furthermore, the interviewees were asked to estimate the market lifespan of the Albufuse® Flex, which was used to determine the roadmap time frame. The theoretical framework presented by King (1994) [52] was used to guide the development of the interview protocol. Fourteen internal professionals were interviewed, all of whom were employed by Novozymes Biopharma at the time of the interview (4 in R&D, 4 business developers, 3 in patent or licensing and 3 in management). Eight were part of the core group, i.e., they worked directly on the project, whereas 6 were indirectly involved (e.g., management and scientists involved in complementary projects). Interestingly, approximately half of the interviewees stated that they derived personal value from being compelled to reflect on the questions that were asked, with particular value derived from the question about project expectations.

Expert panel/workshop

The business development group initiated a project workshop. From the company's point of view, the aim of the workshop was to bring together people involved in the Albufuse® Flex project to initiate the commercialization process. An additional aim of the workshop was to serve as a forum for the company's internal experts to exchange information and ideas, thereby leveraging the group's common knowledge base for the creation of value to the company. The workshop meshed well with the process of this study as it provided an opportunity to validate information gathered from the interviews and literature review while concurrently allowing for important participatory elements of the study to occur.

The core group (n=7), along with a number of indirectly involved internal professionals (n=7, e.g., patent attorneys and management), was gathered for a two-and-a-half-day workshop.

In collaboration with internal professionals [53], one of the authors served as the workshop facilitator. The workshop was divided into seven steps that were directly relevant for the project process:

1. Presentations: Presentations by speakers from R&D and Business Development.

2. Value proposition evaluation and discussion (Appendix II): Open discussion and feedback on value propositions and the valuation of each. This step allowed for interaction and expert feedback.

3. Competitor segments (Appendix I): Participants had been placed into one of four competitor groups (PEGylation[11], depot forming systems, protein fusion, and novel fusions and conjugates) prior to the workshop. Groups were allowed 60 minutes to answer a list of questions about the competitor's technology. Each group subsequently presented their findings.

4. Brainstorming sessions (commercialization): Ideas for commercialization of Albufuse® Flex and albumin were discussed in two brainstorming sessions. Ideas were captured and used to guide discussions.

5. Brainstorming sessions (customer segments): 10 minutes of silent individual idea generation, followed by plenum presentations. The headline questions were: (1) Who are Novozymes' customers for the Albufuse® Flex technology? (2) How can Novozymes reach these potential customers?

6. Data and IP risks, R&D: Scientists and management identified key data that would be generated within the year (in 2011) and mapped these onto a timeline. The timeframe and each data point were subsequently associated with Intellectual Property Right (IPR)risks [6]. All identified data points were rated in plenum on their importance for commercialization.

7. Action planning. Focusing on the timeline (session 6) and ideas for reaching customers (session 5), each idea was rated in plenum according to its importance for commercialization. The most important ideas were subsequently discussed and mapped into an action plan.

Strategic landscape and technology roadmap workshops

The strategic landscape, i.e., factors of the micro and macro environment that could affect the Albufuse® Flex project, were identified. Two workshops were held with internal professionals (n=3 in each). Before the workshops, a list of subjects was prepared, covering external factors and relevant technological parameters. Interviewees were asked to identify the most important issues within each subject over a time period of 20 years. Each issue was captured on a Post-It and placed on the prepared chart. Information from each workshop was collected and organized in a systematic manner, and the resulting overview of the *strategic landscape* was subsequently used to identify

[11] PEGylation is the process of attaching chains of polyethylene glycol (PEG) to a biopharmaceutical (See Appendix I).

knowledge gaps and to provide guidelines for further analysis. The subjects covering technological development and data were later discussed with other internal professionals (3 R&D and 2 business development) to evaluate the results.

Complementary asset identification

Guided interviews were used to identify and rate complementary capabilities (expertise and skills) necessary for commercialization of Albufuse® Flex. The interviewees rated each identified capability in terms of both its importance for commercialization and Novozymes' ability to access the given capability. Information for complementary asset identification was obtained via interviews. Nine interviews were completed with internal professionals (business development, n=4; R&D, n=2; others, n=3), two thirds of whom were members of the core group. Each interviewee was asked to identify and write down complementary capabilities, which were subsequently valuated. The identified complementary assets were concatenated and mapped into graphs. In identifying complementary capabilities, it was observed that interviewees in general were reluctant to give colleagues low scores when valuating Novozymes' access to a given capability. The analysis might have been subject to bias, incorrectly indicating higher involvement by the company in certain areas, but we chose to accept this risk.

Exclusive interview

After the study was presented internally at Novozymes, an exclusive interview was conducted with senior director Svend Licht to reflect upon the application of strategic roadmaps for future management practices and to relate the implications of the study to further development of the Albufuse® Flex roadmap. A semi-structured interview guide based on King's methodology [55,56] was used in this interview (Appendix III).

5.3.3. Phase 3: interpretation and analysis of data and information

Researchers agree that roadmapping can be regarded as a foresight vehicle. Therefore, we argue that technology roadmapping can be chosen as a conceptual framework for long-term strategic planning of specific technologies, their application and potential markets due to their flexibility and the power of their application as a communication tool.

5.3.3.2. Strategic landscape

The strategic landscape surrounding the technology of this case study was analyzed based on numerous methods, from which the main conclusions were condensed into the roadmap. The most important findings of this analysis are summarized in table 4.3.below:

Table 5.3.3.1. Strategic landscape – key trends and market drivers

The main trend in the market is the focus on enhancing patient compliance for biopharmaceuticals by improving the bioavailability, stability and efficacy of biological compounds. This objective, along with the market's increased focus on reducing the toxicity of biopharmaceuticals, creates a market pull for natural half-life-extending technologies for biopharmaceuticals.
Emerging markets are increasingly important, both as sources of potential customers/partners and, in the longer term, as markets for end-product drugs.
The current economic situation (end 2010) has led to the reduction of investments in high-risk projects. This change may be an obstacle for the development of the albufuse project as it will most likely be regarded as a more uncertain solution for drug development compared with more established alternatives, such as PEGylation.
The increased focus on decentralized health care increases the need for self-administration and less invasive drugs. This could become a limitation for the Albufuse® Flex project because the product currently only allows administration via injection.
The increased focus on health economics (the costs versus benefits of drugs) and generic entrance could prove to be both a threat and an opportunity. In general, fewer drugs will gain market approval. However, from this change follows an increased interest in half-life improvements that could provide unique benefits to putative drugs, increasing the chances of drug approval and extend exclusivity.
Merger and acquisition (M&A) trends between pharma and biotech remain, which is a potential

advantage for the Albufuse® Flex project. Furthermore, the trend of big pharma and biopharma outsourcing their R&D will create a sustained advantage for the albufuse project as potential customers will look outside of their own organizations for new products and innovations.

An increased market focus on targeting could become an obstacle for albufuse as targeting is not currently possible with the Albufuse® Flex offering (in the short term).

The competitor landscape for drug delivery is rapidly developing. In the short term (the next 5 years), the main competition will arise directly from companies claiming increased and controllable drug half-lives based on PEGylation, novel conjugations and fusion protein solutions along with existing depot forming systems. In the medium to long term, rapidly evolving and potentially disruptive technologies will become competitors. These not only compete on half-life, but also claim targeting, a broad application range, regulatory compliance, low production cost and alternative routes of administration.

A window of opportunity exists for fusion-based drug delivery technologies (such as Albufuse® Flex). The window is estimated to exist for the next 5-10 years as other versatile technologies, such as particle delivery systems and delivery devices are emerging. These emerging technologies not only possess a broad application range, from small molecules to proteins and nucleic acids, but also permit alternative administration routes. The window of opportunity was identified based on secondary data from market reports and primary data based on the bibliometric analysis of literature development in biopharmaceuticals.

Customers for Albufuse® Flex will be big pharma, biopharma or biotech companies working with therapeutic proteins and/or peptides. Their "pain" will be a need for half-life extension of marketed drugs facing IP expiration, new drug candidates or failed/discontinued candidates (during late-stage discovery, preclinical testing or the attempted development of biosuperiors). Some customers would additionally be seeking ease of production and the sharing of risk.

5.3.3.3. Capability mapping

Assets and capabilities needed for successful commercialization of Albufuse® Flex were identified in the interview process. The asset and capability identification covered a number of steps in a business system, including not only the concept of complementary assets but also technological assets, financial assets, reputational assets, other complementary assets and, to some extent, structural assets [40].

Capabilities identified and discussed in the following analyses will lead to an identification (and validation) of the risk and uncertainties in the roadmap. The basis of the analysis was themes ranging from R&D to marketing, business development (of the licensing business model), and risk management. Within each layer, the interviewees were asked to identify complementary capabilities (expertise, experience and skills) necessary for ensuring that Albufuse® Flex is a commercial success. Following identification of these, interviewees were asked to evaluate each of the capabilities relevant to this project in terms of both its importance for commercialization and Novozymes' accessibility to the given capability. This evaluation scheme was adapted from complementary asset mapping presented by Teece (1986, p. 297) [43]. Subsequent concatenation of results from all interviewees allows for a quantitative presentation of results.

Figure 5.3.3.2. Novozymes capability mapping: Mapping of main themes

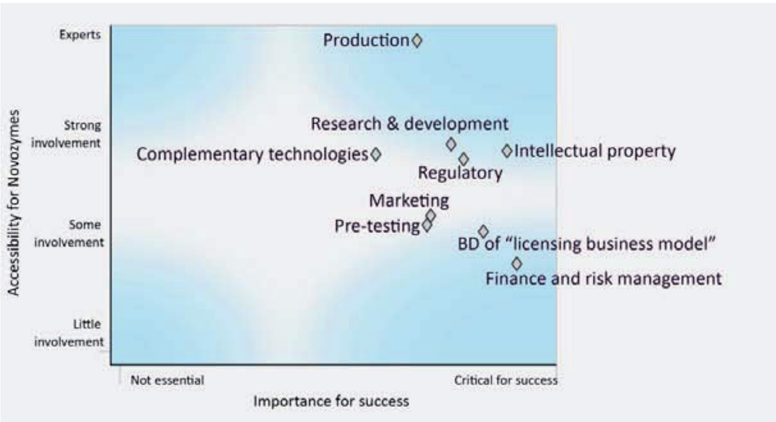


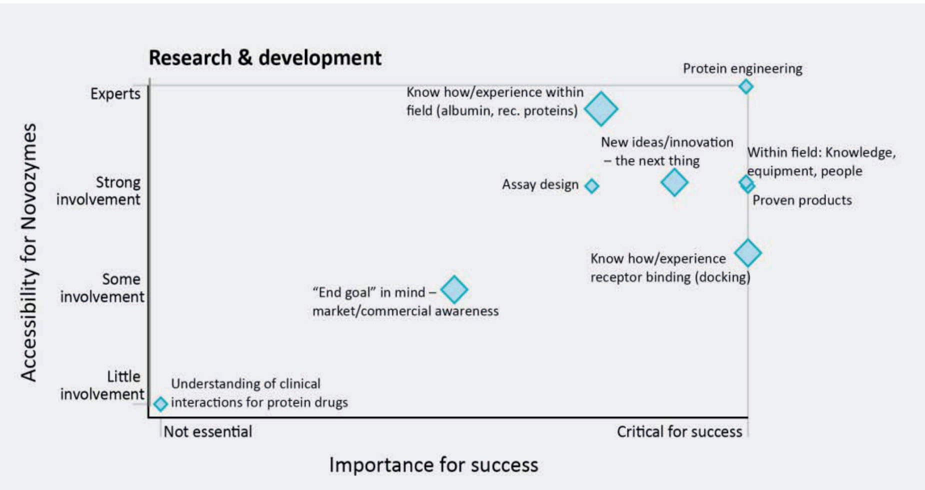
Figure 5.3.3.2 shows a graphic representation of the average position of each of the main themes, taking into account the weighting of frequently stated capabilities. One must keep in mind that internal professionals identified the presented capabilities and that only nine interviews were conducted.

Furthermore, it is important to note that interviewees in general were reluctant to give colleagues low scores when evaluating Novozymes' access to a given capability. The results indicate that capabilities within *production* are classified in group 2. *IP*, *regulatory* and *R&D* capabilities are all regarded as important for commercialization success and stated as capabilities to which Novozymes have access. These are hence also positioned in group 2. This statement is also valid for technologies complementary to Albufuse® Flex, although these are not as critical for success. *Marketing*, capabilities within *pre-testing* and skills, knowledge and experience related to selling licenses in the biopharmaceutical industry (*business development of "licensing business model"*) are all regarded as important for success, but all are capabilities to which Novozymes has limited access. These are hence regarded as group 1 capabilities. *Finance and risk management* is likewise placed into group 1.

The following figures present the mapping of each identified capability within the main themes. The four maps of the greatest importance are primarily those that the previous analysis classified in group 1.

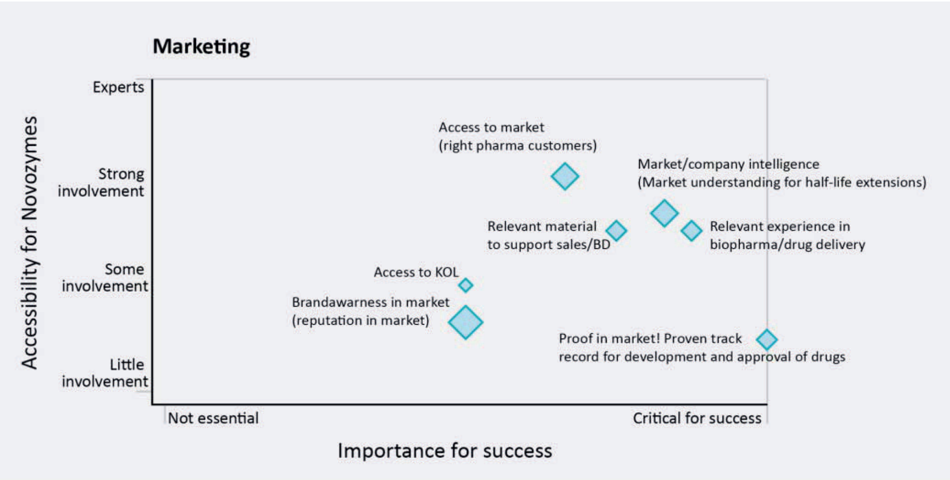
Research and development

This graph depicts the position of each of the specific complementary assets and capabilities identified within the main theme of research and development. The size of each point indicates the number of interviewees mentioning a specific capability.



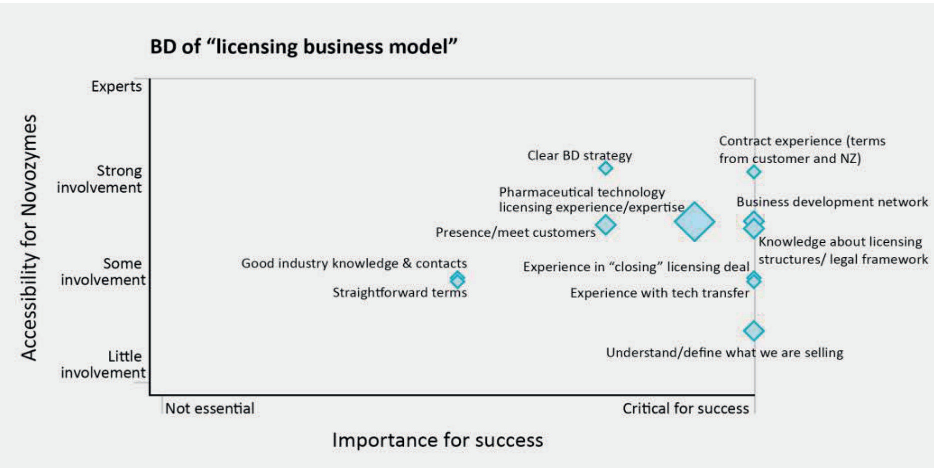
Marketing

This graph depicts the position of each of the specific complementary assets and capabilities identified within the main theme of marketing, which covers marketing activities specifically related to the biopharmaceutical market.



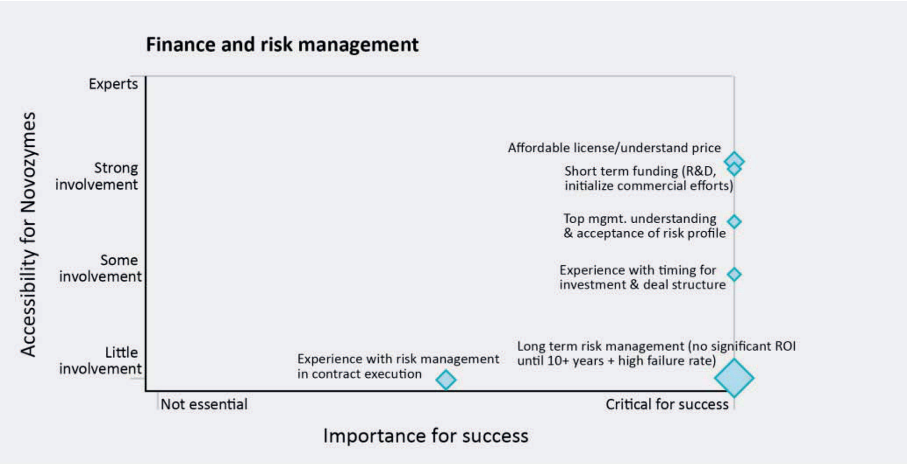
Business development

This graph depicts the position of each of the specific complementary assets and capabilities identified within the main theme of business development, such as the capability to sell the licensing business model in the biopharmaceutical industry.



Finance and risk management

This graph depicts the position of each of the specific complementary assets and capabilities identified within the main theme of finance and risk management in biopharmaceuticals, that is, the capabilities of the organization and the economic resources needed for commercialization of the Albufuse® Flex project.



The results of this analysis indicate that Novozymes has limited access to several capabilities that the interviewees considered critical for the successful commercialization of Albufuse® Flex

Of these capabilities, most interviewees highlighted that final proof of concept studies are critical for success. As pharmacokinetic studies are currently being conducted, this issue may not represent the primary stumbling block to successful commercialization of albufuse. Instead, capabilities that are more difficult to obtain will likely present a higher risk for the future development and success of Albufuse® Flex.

The reputation of Albufuse® Flex in the pharmaceutical market and market proof are both important capabilities that need to be acquired to improve the probability of commercialization success. However, obtaining such market proof is a long-term process that is to a large degree unaffected by Novozymes. Lack of market proof is thus a risk factor that is difficult to change, but it must be taken into account; however, this will hold true for all other companies in the pharmaceutical industry, not merely Novozymes. Market reputation, on the other hand, could in theory be obtained by Novozymes through acquisition of a key firm in the field. Novozymes in serving to visualize needs and opportunities and can thus help guide change”

The dynamic capabilities theory states that many capabilities of a company, such as values, culture, and organizational experience, cannot be bought because they depend on the history of the company. Such non-tradable assets must be built internally [41]. According to senior director, the capability maps have in itself been a valuable eye-opener in strategic planning for commercialization of the Albufuse® Flex, serving to visualize needs and opportunities in structuring change and commercialization strategy. Long-term risk management and the organizational structures to sustain this risk management are thus dynamic capabilities that the company must build if it wishes to succeed in the biopharmaceutical field.

5.3.3.4. SWOT

The SWOT framework was employed to identify strengths, weaknesses, opportunities and threats for Albufuse® Flex commercialization. The key features of information identified through the study process are then mapped into a timeframe, providing a conclusive strategic roadmap for Albufuse® Flex development and thereby employing the roadmapping framework to summarize and present the complex knowledge base acquired during the project.

Figure 5.3.3.3. SWOT summary

There is little doubt that the Albufuse® Flex product offering could provide value in the current market, in which half-life extending solutions are eagerly sought out; moreover, there is a market need for natural drug delivery solutions that improve patient compliance and the bioavailability of biopharmaceuticals. These needs, combined with a strong technology concept and an attractive product offering of albufuse[2.00], create the potential for high ROI. The product offering is further strengthened by value-adding services and complementary technologies, which provide opportunities in the market. A further strength of the albufuse project is that it was developed within the context of an established organization, which ensures that dependable economic and human resources exist for the project.

However, there are also obvious questions regarding whether Novozymes is the correct organization to commercialize Albufuse® Flex, and furthermore, whether protein-fusion platforms are a good solution for long-term business at all. Novozymes does not have extensive experience with developing a product similar to Albufuse® Flex (which is long-term and high-risk, involving licensing deals).

These weaknesses relate to the external threat that Novozymes, as a new player, has low brand awareness in the biopharmaceutical market. As for external pressures, the drug delivery market is highly competitive, presenting difficulties for firms looking to differentiate themselves and create competitive advantage. In this case, protein fusion for drug delivery may be a viable solution for the market in a 7- to 10-year time window.

5.3.3.5. The roadmap

The following section provides a top-down review of each layer of information in the roadmap, which is provided as figure 5.3.3.4.

Market and business

A window of opportunity appears to exist for fusion-based drug delivery systems. Drug delivery solutions based purely on protein fusion will likely be replaced by competitive and disruptive technologies in the next 5 to 10 years, during which time the most important changes to the drug delivery market will likely be caused by nanoparticle platforms and microelectronics. Depot forming systems, which offer many of the same benefits as nanoparticles, will most likely develop ahead of nanotech systems and thereby become an important short-term competitor to existing drug delivery methods. Other competing technologies do not appear to have the same ability to alter customer requirements markedly in the immediate future.

Current market trends create a need for drug delivery solutions such as albufuse. Future market developments, including patent expiration (leading to the emergence of biobetters) and an increased focus on targeting, will impact the drug delivery market in the short term. In the medium to long term, the emergence and expanded application of solutions such as nanoparticles and depot forming systems are predicted to yield new and attractive product features for customers.

In particular, features such as a broad application range for different molecular drug types and alternative administration routes for drugs will drive market requirements towards fully flexible drug delivery systems. This driving force will likely be sustained over the long term, when more drug candidates for truly personalized medicine may emerge into clinical development. Throughout the timeframe presented in the roadmap, figure 3.3.4, regulatory compliance will most likely be an important performance attribute for drug delivery systems. That is, companies will want drug delivery platforms that do not create unique compounds that must pass through all steps of regulatory approval. Development will therefore move towards particle platforms that are approved as a unit and only "combined" with the drug molecule in a later regulatory stage. The later the drug delivery system can be incorporated into the regulatory process, the better, as this is a performance attribute that can minimize regulatory costs for the development of new drugs.

Products and platform technology

To maintain a product offering in which attractive product features are presented to the market, Novozymes needs to develop product attributes that are responsive to market needs. In the current development step of the albufuse platform (Albufuse®Flex), it is possible to achieve an extended and controllable half-life of therapeutic proteins. These product features are based on the technological development achieved in the FcRn-albumin work and studies of the albumin docking model. This product offering shows good market potential with strong internal support and trust in the basic technological capabilities.

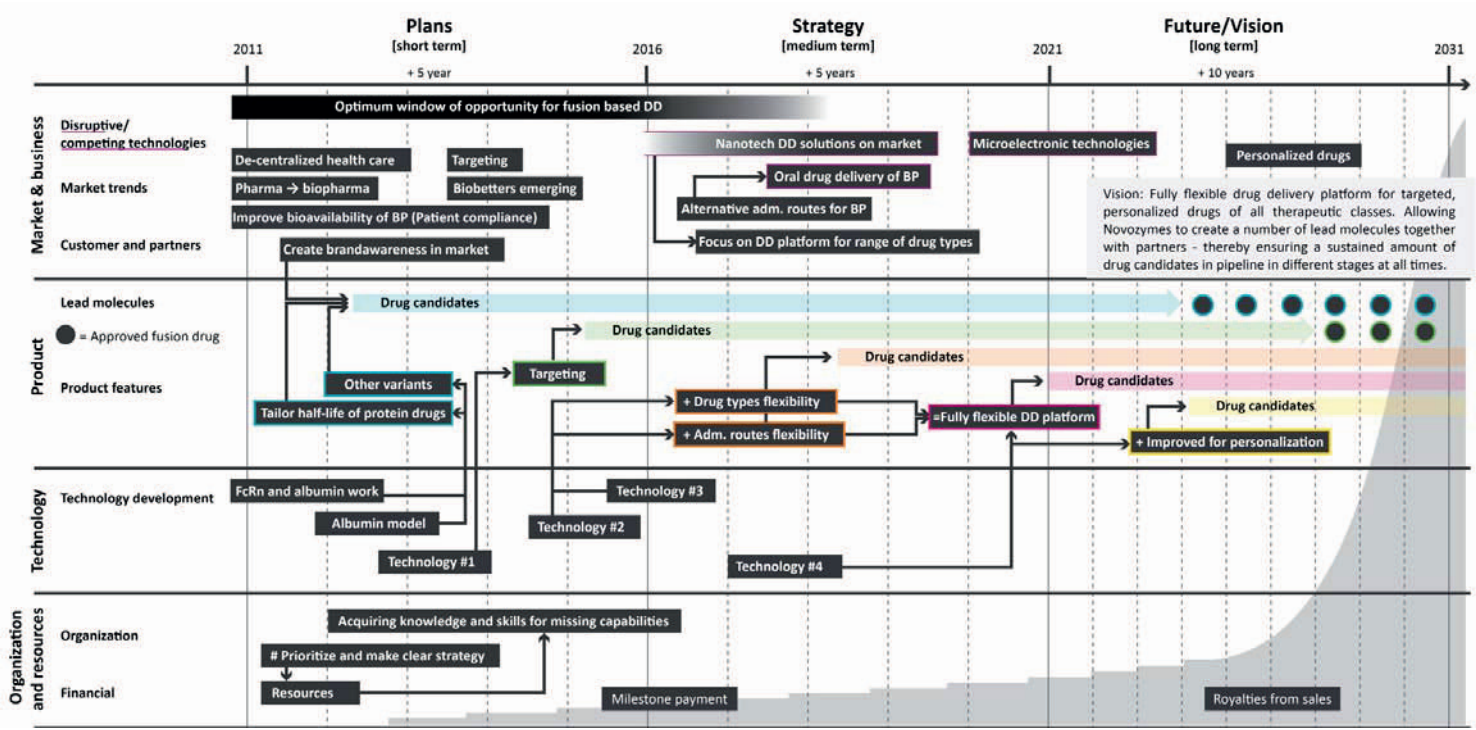
Each square presented in the roadmap, figure 3.3.4 illustrates the initiation of a licensing deal, i.e., when the development of a fusion-based drug candidate is initiated (more than one deal can be initiated per year). New deals for development of drug candidates based on a specific product feature are initiated each year over a period of 10 years. With a first licensing deal initiated in 2012, sales of fusion drug products could potentially start in 2024 (base case), as indicated with circles. However, for initiation of drug development deals to occur, brand awareness in the biopharmaceutical market must be established. Further development of product features should introduce a broader application range of drug types and alternative administration methods to compete with the changed market requirements described above.

Organization and resources

In the identification of capabilities, it was found that Novozymes has access to important manufacturing and technological capabilities. However, the analysis also highlighted a short-term need to build the firm's reputation in the market and expand its internal experience in business development based on technology licensing in the biopharmaceutical field. Obtaining access to these capabilities requires short-term funding, which leads to an important realization: if technological development is to progress, as presented in the roadmap, in which attractive product features that meet market needs are developed, resource allocation will be required in the very short term. With the fast pace of market development and emerging disruptive technologies, there is a great risk of being left behind if Novozymes' technological development does not keep pace.

Directing sufficient resources to the Albufuse® Flex project needs to be followed by the development of risk management capabilities for the roadmap to become a reality. Novozymes' management must in this case accept that present-day expenses will only result in significant earnings beyond 2018 (a significantly different business model as the company usually operates), as schematically mapped in the roadmap (grey marking at bottom of figure).

Figure 5.3.3.4 The 20-year <u>explorative</u> roadmap for the Albufuse® Flex project



Notes on figure 5.3.3.4: DD: Drug delivery, BP: Biopharmaceuticals, * Diamonds indicate early stages in fusion product development,

** Circles indicate late-stage drug candidates that have reached the market.

The explorative roadmap illustrated in Figure 5.3.3.4 shows the possible development of the Albufuse® Flex project. The presented roadmap is based on general roadmapping structures for strategy planning. Each box represents a parameter that was identified as important. Parameters are mapped into one of the presented layers: market, product, technology or organization. The left-hand side of the box relates to the time frame; parameters with the left side placed outside of the 2011 line are therefore already present. An inherent feature of roadmaps is that uncertainty increases with time. The colored boxes in the product layer show relations; for example: Products including targeting (green line) lead to ten years of new drug candidates in development (green squares), which will potentially result in the first product sales in 2028 (green circles).

Development of a sustainable and long-term drug delivery business, as presented in the roadmap, will require continuous technological and business development focus along with recourses. This business focus on the drug's development requires a strategic decision about the company's future commitment within drug delivery, followed by resource prioritization (at the decision point marked with # in the roadmap). These choices form the basis for scenario testing and discussion.

5.3.4. Roadmapping results

Commercialization of Albufuse® Flex introduces a high risk as the product offerings might be difficult to differentiate in the market. With a limited temporal window of opportunity for protein fusions, Albufuse® Flex might not realize the economic potential projected in financial models. To improve the probability of building a sustainable drug delivery business, the Albufuse® Flex may be developed as a platform solution onto which product features are constantly added to maintain attractive product attributes for the changing market. However, to create a drug delivery platform, strategic choices must be made. A long-term strategy for involvement in the biopharmaceutical area must be defined, so a sufficient organization for the high-risk profile projects required in this regard should be built. This step needs to be followed by resource allocation to build Novozymes' capabilities in marketing and business development and, importantly, to direct technological development towards creating the next novel product. A scenario test based on this line of reasoning is presented in the following chapter, along with recommendations generated by this case study.

5.3.5. Scenarios

A biotech company such as Novozymes is continually faced with challenges to develop products of improved quality at a lower price. Ideally, these products could also be pushed through pharmaceutical quality tests more quickly [54]. The Senior Director of Novozymes Biopharma, who is directly responsible for commercialization of technologies, emphasized the roadmap process as a valuable current practice because Novozymes looks at trends in the surrounding environment to identify the technologies for which they want to pursue commercialization:

This has led to competitively focusing on what Porter's theory says we can't do: price-performance and quality (Licht, interview, 2011) [54]

Scenario analysis is an important use of roadmapping that, in this case, explores possible commercialization paths for albuflex$^{2.00}$. In general, roadmapping may be linked to scenario testing by the development of a roadmap for one commercialization scenario and used to identify the key decision point for moving towards the currently defined vision. Scenario analysis may then be performed by identifying different and equally likely outcomes at the key decision point and relating these to their effects on other parameters of the roadmap. Thus, the scenario analysis uses the roadmap to describe alternative commercialization strategies. This combination of roadmapping and scenario testing is consistent with case examples presented in a study by Rohrbeck and Gemünden (2011) [57], where they describe different approaches to combining roadmapping and scenario analysis. Of these, our study may be characterized as an example of what they call "project one type", which is first to develop a situation analysis to understand the macro- and micro-environment and then to translate the information into a roadmap to formulate the questions that would frame the path development.

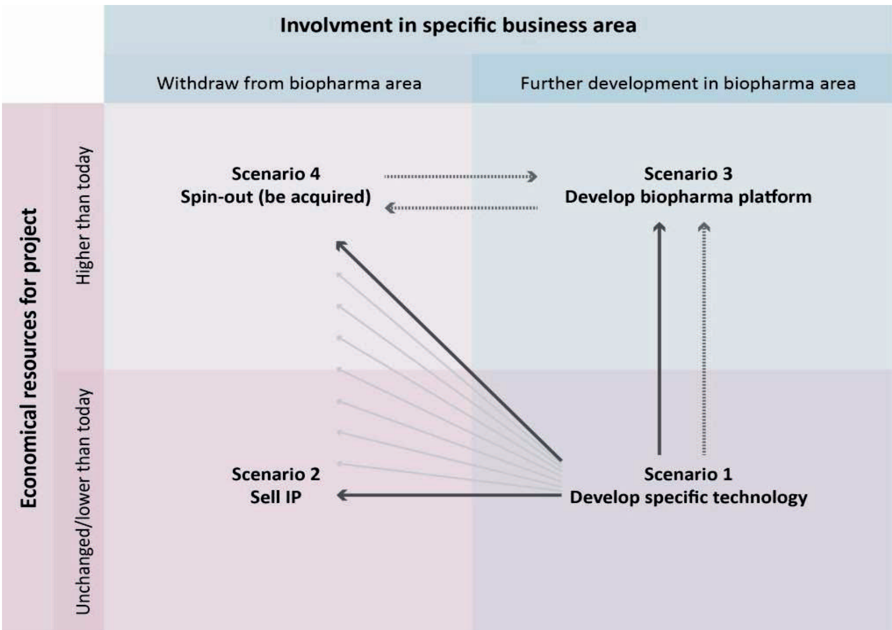
As a number of likely outcomes from the strategic decision exist, it is relevant to test the possible scenarios. A scenario test is therefore provided to aid the decision-makers in understanding the paths ahead and the risks and opportunities of each possible scenario. At the defined decision point, there appear to be two main strategic choices that relate to the Albufuse® Flex project:

(I) Novozymes' involvement in the biopharmaceutical industry, specifically drug delivery: Capabilities and time are of the essence. The company must presumably make and communicate a clear decision regarding whether to continue or cease development in biopharma. It appears that the current situation, where biopharma has a minor position within a subdivision of the company, creates frustration and problems; moreover, the company's focus on short- to medium-term projects unnecessarily constrains and impedes development of the albufuse project.

(II) Resources for development of the albufuse project: In terms of resources for the albufuse project, two main possibilities exist, namely, that the company could choose to maintain current funding levels or increase resources provided to the project.

These two strategic choices are best illustrated in Figure 5.5.1 along with likely and equally plausible outcomes. The potential outcomes from the strategic choices are based on *extremes* to allow for scenario testing. Scenarios 2 and 4 are, for instance, the outcomes of the extreme possibilities of only selling IP and a spin-out strategy, respectively. Novozymes could, for instance, choose to develop the platforms for a period of time and then sell them along with its contracted expertise. However, for the sake of scenario testing and to aid in understanding possible future paths, it is beneficial to include the extreme outcomes in analyses.

Figure 5.5.1. Possible scenarios departing from the main decision point



The figure constitutes a 2x2 matrix showing possible outcomes of the two main strategic choices. The horizontal axis relates to choices, regarding Novozymes' future involvement in the biopharmaceutical industry. Extreme outcomes are either to stay and expand activities or to cease development in the area. The vertical axis corresponds to choices regarding resources for development of the albufuse project. Extreme outcomes are either to maintain the defined resource level for the albufuse project or to increase resources significantly. Scenarios 2 and 4 are examples of extreme outcomes as a number of intermediate possibilities exist between these potential scenarios.

Maintaining the current situation appears to create high risks (Scenario 1) as resources for development are limited and the road forward for engagement in biopharma is unclear. In Scenario 1, the main risk is that the technology will not live up to expectations; it might become unattractive before the company develops substantial brand awareness and capabilities for technology licensing in the biopharmaceutical market. Without further development of the technology, the competitiveness of the product offering ("only" Albufuse® Flex with no further development) and the ability of the company to differentiate its offerings in the marketplace will also be a risk factor.

The scenarios presented here, although they are presented as extreme outcomes, appear equally likely. A key recommendation from the project analyses conducted here is that Novozymes should address the identified strategic decision point and communicate the path ahead. In addition, capability maps, when related to the timeframe in the roadmap's window of opportunities, can provide insight into the right time to seek a partner and what the criteria for such a partner might be.

5.4. Discussion and conclusions

The foundation of this study was the use of the technology management tool, technology roadmapping, as a flexible framework to guide the collection and organization of information. Roadmapping was utilized as a carrier of knowledge, allowing for the presentation of complex information on many levels. The communicative ability of the tool has proved invaluable. Using the strategic roadmap, the importance of identifying an important decision point in the present has been identified and highlighted. Such identification can provide managers who address the commercialization of new technology with information regarding the appropriate timing of actions relative to market conditions.

5.4.1. Lessons for academics

The value of roadmapping in this project is related to the “strategic lens” analogy presented by Phaal and Muller (2009) [35] in that roadmaps help companies like Novozymes to view and communicate technological development in ways that create strategic dialogue and facilitate long-term business planning.

Researchers have argued that participative processes and team iterations are important for successful implementation of roadmapping in corporate settings [11, 29]. However, it appears that participatory processes can also be a challenge for successful roadmapping in companies. As we noted when working with the conceptual framework, the challenges include keeping the process “alive” and the risk that managers are reluctant to share key information in participatory processes. Based on this case study, it is therefore argued that implementing roadmapping as an information carrier could introduce an alternative application of technology roadmapping, broadening its usage. However, it appears to be specifically valuable to use case studies, combined with theoretical analyses, to understand if roadmapping can serve as a framework for these broader purposes and thus create value as a tool for handling and sharing knowledge.

5.4.2. Lessons for managers

According to Svend Licht, Senior Director of Novozymes Biopharma and responsible of the commercial strategy on the Alfubuse® Flex, the applied framework has added value to the company by identifying the strategic choices that must be made to achieve the successful commercialization of the drug delivery platform. As a result of the participatory processes and analyses involved in this study, a roadmap framework was generated that created valuable perspectives regarding how to develop long-term commercialization strategies, focusing on developing a platform technology solution, and not just focusing on one technology. This framework enables the company not just to profit from a single innovation in the present, but also to develop a competitive strategy for the future that is focused upon the long-term potential of new technologies. In particular, the work discussed in the current analysis has contributed to the creation of a process that inherently incorporates the dynamic capability not only to sense and seize new opportunities, but also to (re)direct resources and establish partnerships in time. Since this study’s completion, Novozymes filed the relevant patent for what is now called the Albufuse® Flex platform, which February 2012 received the 2012 Drug Delivery Partnerships Innovation Technology award in Las Vegas in for being the most promising technology.

Combining roadmapping and scenario testing proved to be a valuable perspective in the case study presented here. The strategic roadmap identified two important decision points for future strategy regarding which outcomes should be tested using scenario analysis, allowing for a better understanding of the inherent uncertainties within the roadmap.

In this case, it was the early commercialization perspective on Albufuse® Flex that altered Novozymes' focus from one technology to the vision of a bio-platform of the future, and thereby as senior director phased it in the interview: "making it possible to competitively focus on what Porter's theory says we can't do: price-performance and quality" [54].

Using explorative roadmapping integrated with dynamic capability thinking demonstrated clarity in path creation and produced definitive findings regarding which capabilities the firm should use at which time to reach its desired goals. As a result, the study has provided the decision-makers at Novozymes with an extended knowledge base relating future trends and market drivers to resource management. This knowledge base can be employed to make strategic decisions about the technological development of the bio-platform in question. Analyzing commercialization based on a practical roadmapping method, yet from a dynamic capabilities perspective, proved to be valuable because commercialization comprises more than simply market size, product value and competition. Successful commercialization of technologies also depends on the capabilities of the firm. For a firm that wants to build a sustainable business, the roadmapping approach allowed for analysis of a relevant question from a broader perspective, focusing on market trends and market drivers (a market pull strategy). This analysis renders commercialization a process that does not merely consider the profit from one technology in the present, but also ensures that commercialization will incorporate a strategy for the future, truly justifying the term "strategic roadmapping".

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5.6. Biographical endnote (of authors)

Lykke M. Ricard is a PhD scholar from Technical University of Denmark, Department of Management Engineering, where she has specialized in roadmapping, strategy and innovation system thinking. She holds a Master of Science degree from Copenhagen Business School in 2003, and has experience in business improvement process from working in industry.

Julie Serritslev holds a Master of Science degree in Systems Biology from Technical University of Denmark, where specializing in biopharmaceuticals. Julie currently works as strategy manager in private industry.

5.7. Appendices

5.7.1. Appendix I – Main drug delivery technologies

The tables below give details of drug delivery technologies that were identified as most important in the market for delivering biopharmaceuticals. The technologies are divided into two main groups: (1) *biochemical modification*, which covers technologies where the protein is directly modified, e.g. by attaching a chemical group and (2) *particle delivery systems* where the effects of the biopharmaceutical is optimized without direct modification of the protein.

Table IV.1: biochemical modification technologies

PEGylation	
Description and advantages	PEGylation is the process of attaching chains of polyethylene glycol (PEG) to a biopharmaceutical. By this the molecular characteristic of the therapeutic changes with the results being: improved solubility, improved binding affinity to cell receptors and change absorption and distribution patterns resulting in longer half-life. PEGylation have furthermore been argued to mask the therapeutic from recipient immune system thereby decreasing immunogenicity.
Technology maturity	PEGylation has developed since 1970's and is today the most established drug delivery technology for biopharmaceuticals. Currently (2009) there are eight marketed biopharmaceuticals using PEGylation.
Innovations and development	A number of disadvantages were seen in first generation PEGylation, among there were limited flexibility in PEG molecules and attachment profiles along with heterogeneity of end-product resulting in expensive post-production. Second generation PEGylations, which have resolved many of these issues have developed since the beginning of the century. PEGylation are today also developed for combination with other drug delivery technologies such as liposomes and hydrogels. Furthermore a number of alternatives to PEGylation are emerging where biological polymers, that are degradable by humans, are used, e.g. poly sialic acid (PSA).
Protein fusions	
Description and advantages	Protein fusions are biopharmaceuticals constituting both a therapeutic and a drug delivery molecular part. These are constructed by genetically combining a therapeutic protein with a fusion molecule on the same DNA strand, which result in production of a single molecular entity. Currently used fusion molecules are human proteins with long half-life and includes immunoglobulin Fc-regions (antibodies), human serum albumin and transferrin. By using natural human carrier and at the same time increasing the size of the therapeutic protein, protein fusions obtain longer half-lives. Furthermore fusion proteins allow for improved receptor binding often resulting in favourable tissue distribution.
Technology maturity	A number of marketed drugs based on immunoglobulin Fc fusion exist along with a large number of industry players. No marketed products exist based on either transferrin or albumin, but a number drug candidates based on albumin fusions are currently in pipeline. There is in general less focus on albumin and especially transferrin based fusions compared to antibody-based solutions.

Innovations and development	New protein fusion platforms are currently developing with improved capabilities for targeting, and in general introducing flexibility of the platform e.g. tailored half-life and targeting with e.g. Ablynx's Nanobody® Platform and the Albufuse® Flex project are example of technological innovations within this. Observers have highlighted development of novel antibody fragment as the main trend within protein fusions.

Conjugation	
Description and advantages	Protein drug conjugations involve combining both a therapeutic and a drug delivery molecular part using chemical/physical attachment (non-genetic). Conjugation technologies have to a large extended the same advantages as fusions but furthermore allow for a broader use of molecular carriers and can be employed on non-protein drugs. PEGylation is specific form of conjugation.
Technology maturity	Novel conjugation for biopharmaceutical drug delivery is not as well established as either fusions or PEGylations, but a number of drug candidates are currently in pipeline
Innovations and development	Innovations follows the same trends as highlighted for PEGylation and fusion proteins, that is flexibility and targeting for instance allowing biopharmaceuticals to cross the blood brain barrier. Observers have highlighted development of novel conjugation technologies as important in the medium term (approx. 5-10 years) technological landscape.

A biopharmaceutical can furthermore be biochemical altered by attaching specific carbohydrates (glycol-engineering) or acetyl groups (acylation) thereby changing the characteristics of the protein. It is moreover possible to make protein analogues by altering characteristics of a therapeutic protein by changing amino acid (amino acid substitutions) in the primary structure without altering the therapeutic function.

A number of marketed products exist employing this strategy.

Table IV.2: particle delivery systems

Nanoparticles	
Description and advantages	Nanoparticles for drug deliver cover a broad range of nano-sized (less than 100 nm) drug delivery vehicles. In general drug molecules are incorporated into the nanoparticle with the result being, that as long as the drug is encapsulated in the nanoparticle it will have pharmacokinetic properties based on properties of the particle. The potential benefits are: controllable release, long half-life, reduced toxicity, enhanced drug stability and improved biodistrubition due to small size and potential for targeting. Extra advantages of nanoparticles are the applicability on a broad range of drug molecules and the ability to allow for co-delivery of multiple drugs. Nanoparticles generally cover a large number of technologies: metallic nanoparticles, lipid-based nanoparticles such as liposomes, polymeric nanoparticles, and Biological nanoparticles such as viruses. Some of these are degradable by the human body. Nanoparticles have been combined with other drug delivery technologies, e.g. PEG. Lundstrom (2009) gives a good review of different

	nanoparticle types.
Technology maturity	Nanotechnology for drug delivery has been characterized as an emerging technology, and there are now a number of products based on nanoparticles in clinical test.
Innovations and development	A large number of companies are currently pursuing research in the area of nanoparticles for drug delivery. Nanoparticle development is currently focused on creating targeting capabilities primarily for oncology so that nanoparticles are able to detect cancer cells. Developments in the field of nanotechnology for drug delivery are furthermore focused on allowing delivery of biological molecules by alternative routes such oral, topical and pulmonary.
Depot-forming, slow release systems (*In Situ* depot forming systems)	
Description and advantages	Depot forming systems are generally based on so-called carriers, which a given biopharmaceutical is mixed with. Upon administration a solid depot is formed at the site of injection – from which the drug will be slowly released as the depot degrades. These systems have showed good long terms stability and low toxicity. They have furthermore been highlighted as a cheaper and easier to produce and a system that can be applied on different drug types. Different classes of depot forming systems exist: Precipitation systems based on water-resistant biodegradable carrier, thermal gelling systems based on carriers that transform to gel at body temperature, cross-linked systems that consist of cross-linked polymers and so-called thermoplastic semisolids based on flexible dials (see Lundstrom, 2009 for a review).
Technology maturity	Depot forming systems are like nanoparticles characterized an emerging technology currently getting much attention. Number of products employing depot-forming systems is somewhat equal to product employing nanoparticles, but the number of companies pursuing research is in the field cannot match the numbers seen in nanoparticle development.
Innovations and development	Depot forming systems are still in a development phase and current development focus largely on improving the systems and prove them in clinical trials. Current developments within the area also focus on novel carrier types and alternative delivery routes.

5.7.2. Appendix II - Overview of valuation criteria's

The table shows the valuation criteria's that each product and service attribute has been evaluated by.

Scale from low (L), medium (M), and high (H).

Subject	Description
Value for customers	
Summarized: Value creation for customer	In overall terms is this attribute, seen separately, likely to create value for customers (a summary of the following terms)
Reduce customer cost	Will this attribute reduce customers cost e.g. by reducing time to market or reducing production time?
Reduce customer risk	Would the inherent risk that customers have when bringing drug candidates to market be reduced by this attribute? Do the attribute for instance improve the likelihood of market approval.
Increase customer sales/revenue	Could this attribute, seen separately, result in increased sales? This should be evaluated by comparing the product with and without the given attribute.
Reduce customer capital expenditure	Would this attribute alone reduce the customer's capital expenditure, for instance by providing manufacturing services?
Economic value for customer	Would the attribute on overall terms generate an economic value for the customer, and would it be high, medium or low.
New in market?	
Summarized: Is it regarded as new?	To which degree would the attribute, seen separately, be regarded as new or already existing in the marketplace? From completely new to neutral to always there.
To which degree do customers expect it?	Would all customers expect that this attribute is offered, or would it only be some or none at all?
To which degree does the competition offer it?	Do all, only some or none of the competitors provide this attribute (or is equal)?
Details	
Is it a service or product inherited feature?	Is the attribute related to the product albufuse[2,0], or is it a complementary service. Services can generally be contracted elsewhere while product attributes must be provided with the product.
Would customers be dissatisfied if it was not provided?	Is it expected that customers find the offering as a whole dissatisfactory if this attribute is not presented.
Relation between customer satisfactions and attribute.	Would the degree to which this attribute fulfils its function haven an influence on customer satisfaction? Neutral/expected, yes would be proportional, yes would be more than proportional.
Value for Novozymes	Would the attribute, seen separately, give value back to Novozymes, both economical and non-monetary?

5.7.3. Appendix III: Guide for interview on the roadmapping process in Novozymes Biobusiness

Basic information about the respondent, please indicate the following:

Full name:

Your organization and country:

Position and title:

Could you give a short description of your job?

For the interviewer, please, tickle in the following table about the respondent:

X Expert

□ Generalist

X with leadership responsibilities

□ without leadership responsibilities

In your opinion how would you characterize Novozymes as a player in the (bio)pharmaceutical market?

Technology leader

Technology follower

New entrant

Other

1.1. Can you give any examples of measurements to support this position?

1.2. What is your estimate of the potential in this market?

1.3. In your opinion how does this position fit with Novozymes new long-term development/ growth strategy?

1.4. And are there any relations to the new architecture of Novozymes branding strategy?

(Any related changes)

How many years of experience do Novozymes have with the albumin fusion technology? And how would you characterize this position? Technology leader, Technology follower, Other (?)

In your opinion what is the vision for Novozymes in the (bio)pharmaceutical field?

And in your opinion how strong is this vision in the division (BioBusiness)? 1-5, where 5 is the strongest?

And how strong would you estimate it to be in Novozymes? 1-5, where 5 is the strongest?

Can you revile what the future vision is for the Albufuse® Flex?

Can you revile what the future milestones are in this relation?

What do you see as the most important capabilities needed for reaching the vision of the Albufuse® Flex?

Have the study (commercialization analysis using technology roadmapping) in your opinion added any value to your decisions/current plans?

In the roadmap there is pointed at a so-called window of opportunity: Do you see this as valuable? How?

(Would they for example be useful in deciding on building up these capabilities in-house or partnering?)

In your opinion is partnering a solution in order to access important capabilities in time?

If yes is the window of opportunity pointed at in the roadmap helpful for identifying criteria for partnering? Why and how?

Do you see the roadmap method as possible to apply to your practice? How to you see the challenges in working with a long-term perspective as in the roadmap?

In your opinion is the visualization of the capability mapping helpful in strategy-making?

Did the study have any impact on your current management practice?

Are there any pitfalls in these foresight models as you see it?

What advice would you give to other managers? What lessons to pass forward?

In your opinion what do you see as future challenges for managers working with commercialization and sustainable strategy-making in biotech?

Are there other issues that haven’t been mentioned, but that you find important?

6. Chapter six: Discussions and conclusions

6.3. Discussion of findings: chapters one, two, and three

In both chapters two and three, I have investigated the context of the sector-level roadmapping processes of the ETPs in wind and CCS. Both technologies are considered to be key technologies to enable solving certain important societal issues, i.e. the 20 percent reduction in carbon dioxide emissions and 20 percent renewables to be implemented in the European energy system by the year 2020. These are current issues due to climate change, energy supply security, and European competition enhancement.

Findings support the generally accepted notion that there is no 'one size fits all' when it comes to directing systems of innovation in applying policy or designing foresight practice. Each system is characterized by connectivity evolving around certain time-related problems. The system of innovation approach seems to go hand in hand with EU's innovation policy. Originally, the system of innovation approach was developed with strong roots in evolutionary economics.

The results of the case study on the ETPs indicate a stronger focus on involving actors from the business community in the EU Commission's work on constructing the EU Framework Program, and on setting the overall priorities for EU resource allocation. Innovation policy is focused on the overall innovative performance of the entire economy and not just the science communities.

Foresight practice and tools supporting multiple actors with various stakes in and expectations for the future technology are used in building new networks and consensus around common visions. By bringing new actors from the business community into the strategic debate, the common vision also becomes more commercial. In addition to a coordinated effort to bring these technologies closer to the market, knowledge transfer is necessary. The case study also shows that knowledge exchange focused not only on technological issues, but also on social, environmental and economic aspects related to public policy and public acceptance. While CCS is struggling with public acceptance and policy frameworks, wind turbines are moving offshore to meet the public acceptance challenge caused by larger and louder turbines, only to discover later that new challenges continually occur, and new organizations are formed to protect such interests as shipping lanes, bird migration and other offshore environmental issues. My investigations support a general observation in the system of innovation theory that what serves as 'best practice' in one system is not likely to be transferable to another (e.g. Edquist, 2005; Lundvall and Borras, 2006). In my case studies, the challenges for these technologies in solving grand societal challenges are shaped by many factors and not only by:

(a) the technology – its maturity/immaturity as such – but also by
(b) the actors involved – their anticipated intelligence and the roles played and relationships among utilities, suppliers, manufacturer and research
(c) and by the amount of resources necessary to mobilize actors. As learned from the CCS case, the technology is so expensive that the investment for making it commercially viable before 2020 would be massive. Logically, this issue is mirrored by the stakeholders, which need to include outsized, well-established firms.

Simply setting targets as a tool for strategy implementation tends to involve few people and to have low impact. The background for EU policy learning is a history of failed targets; and therefore, a need to look at alternative methods for strategy implementation. This new form of cooperation between the EU Commission and industry is moving beyond lobbyism, and thus becomes important for the legitimacy of the policy processes, for who is inside/outside the decision-making system, and whether they can stay open to innovation and avoid the status of 'clubs'.

As stressed in the interview with civil servant specialist, Tostmann, Head of DG energy, European Commission, a common theme in EU research policy is the constant concern that EU is spending all these money on research – but are there any effects? Increase in competitiveness and innovation seems to be the aim. Today, these are strong European Union themes, and of course when the themes are innovation and competitiveness, it is not really the research communities that are being addressed, but primarily the industrial business communities. This means that from the EU policy perspective, change processes moved slowly because important key players were missing, as if this actor group were analogous to a missing component in the innovation system machinery.

Strong coordination requires strategic coordination based on a common vision and strategy. Here, roadmapping is particularly strong as it provides a systemized tool to guide a technology towards a desired future. However, at sector level, it would require ownership and a strong infrastructure in order to ensure shared actions. This seems possible with the resources the central actors can offer – meaning that key players can offer the vision and research agenda outlined in the roadmap – an infrastructure.

One thing about state policy is that it comes up short on an international level. Networks are a much stronger entity, since innovation and science move beyond national borders. Using social network analysis (SNA) of the two platforms at two points in time showed that when there is a change in the problem, connectivity changes accordingly. This means that innovation systems must be considered dynamic; otherwise, they are simply clubs. The quantitative analysis of SNA was carried out using Ucinet 6. SNA is one approach for identifying structural configurations of key players and examining connectivity in the processes and dynamics. SNA provides a supplement to methods based on the idea of innovation systems.

6.1.2. Implication for Policy

Supporting the establishment of networks by introducing new policy tools such as the ETPs, show signs of experimentation. There is no such thing as 'one size fits all', when it comes to innovation and policy. The aggregate level tells us nothing about the structural processes and dynamics that create the variety of innovations in the micro-level processes. In the case of the European Technology Platforms, the EU Framework program serves as an implementation system, but there is more at stake than R&D prioritizing. It is also necessary to create the right incentives with respect for the dynamics between firms and organizational institutions in the innovation efforts in the micro processes. It is necessary to understand that entrepreneurship is more than a lonesome cowboy; it also encounters institutions and large well-established industries, when it focuses on how systems of organizations work around an entrepreneurial vision.

6.1.3. Future research

Stakeholder involvement seems important for ensuring implementation of the vision and the roadmap, and this alone makes the processes strategic. It is far too early, however, to have a sufficient basis for measuring the effect of the ETPs, especially as they seem to continue beyond the joint technology initiatives.

In the future, it will be important to look into the pitfalls or trade-offs of this new phenomenon as a new way of institutionalizing the bargaining mechanism of new technologies. It will also be necessary to look at the use of systemic foresight methods at a higher level. While the ETPs serve as fertile ground for foresight activity, the use of foresight activities in a systemized manner is fairly low, while in terms of stakeholders, networking activities and problems of knowledge sharing, foresight theory can learn much from practice. Most important is the notion that innovation systems, especially today, are something beyond national policies. While EU technology policy is still picking the winners, innovation systems seem to be open systems consisting of connectivity evolving around specific problems: when the problem changes, connectivity seems to change in a way that makes sense in solving the problems. This study opens up evolutionary research tracks using longitudinal studies, including the potential of social network analysis (SNA) in order to unfold the knowledge that lies in the structural changes of innovations systems, and over time understand the impact of such factors as policies, foresight activities, and technological standards.

6.4. Discussion on findings: chapters four and five

Chapter four comprises a practical guide to foresight activity for exploring strategy and innovation – it combines theory of scenarios and roadmapping. The chapter is based on a guide tested on 25 leading specialists at a one-day workshop and later fitted to the European Foresight Platform template before being published. The specific context was left out due to matters of confidentiality, but it can serve as a practical guide for combining scenarios with roadmapping in participatory workshops, gathering intelligence among participants or creating a boundary object using roadmapping as a light strategic management framework.

In chapter five, the method of roadmapping at the firm level is conceptually integrated with theories of dynamic capabilities from the strategic management literature, specifically from the resource-based view of the firm. Theoretically defined dynamic capabilities go beyond capabilities for routines and practice embedded in a corporate culture; often, routines and practices rather create strong path dependency, whereas dynamic capabilities are enablers in path creation. Dynamic capabilities perspectives draw on the literature and are discussed in chapter five. The short definition highlighted is that dynamic capabilities are sensing and seizing new business opportunities, while redirecting resources in time. On the one hand, roadmapping in corporate settings has mainly been a matter of terminology and less a participatory process in applied corporate settings as scholars of roadmapping imply. On the other hand, the value of roadmapping in this thesis is related to the "strategic lens" analogy presented by Phaal and Muller (2009) that roadmaps help companies view and communicate technological development in ways that create strategic dialogue and facilitate long-term business planning.

At the firm level, the theories of dynamic capability seem compatible with roadmapping as a foresight vehicle. Path dependency is a strong challenge to path creation. In chapter five, the theoretical discussion establishes a technology management focus on development of technological capabilities, while the dynamic capabilities framework covers much broader capability types. In the case of Albufuse® Flex, one of the key learning points was identification of missing capabilities in some areas, proving that the company's path dependency challenges its development and entry into the field of biopharmaceutical drug delivery. The approach seems to have been beneficial, however, since the process led afterwards to a partnership drug-delivery platform solution. For a company that wants to build a sustainable business, the roadmapping approach allows a valuable broader perspective that makes commercialization profitable, not just for one technology in the present, but by developing a commercialization strategy for the future.

In the Albufuse® Flex case, the identified capability maps subsequently served as input for the roadmap, thereby introducing into the roadmap not only technological capabilities but also capability in a much broader sense. Although this process was successful and helped develop understanding of the capabilities needed for future development, the process presented here was a simple implementation of combining dynamic capabilities and technology management. Further case studies must be performed, if a defined methodology for combining the frameworks is to be developed.

6.4.1. Implications for managers

The Senior Director of Novozymes' Biopharma, who is directly responsible for the commercialization of technologies, emphasized that Novozymes looks at trends in the surrounding environment and identifies the technologies for which they want to pursue commercialization based on those trends. He emphasized the need to stay competitive by developing products of improved quality at a lower price, along with possibly pushing technologies through pharmaceutical quality testing process at a higher pace. In this case, it was the early commercialization perspective on Albufuse® Flex that altered Novozymes' focus from one technology to the vision of a bio-platform of the future, and thereby as Senior Director phased it in the interview: "making it possible to competitively focus on what Porter's theory says we can't do: price-performance and quality".

6.4.2. Future research

Researchers have argued that participative processes and team iterations are important for successful implementation of roadmapping in corporate settings. However, it appears that participatory processes can also be a challenge for successful roadmapping in companies. As noted, when working with the applied method, the participatory processes face the risk that managers are reluctant to share key information. Based on the challenges faced in applying the method in Novozymes, it was necessary to counter the risk in the data gathering by conducting interviews with key managers prior to a larger workshop that then concerned more specific tasks such as identifying product features and valuating attributes.

I would then argue that implementing roadmapping as an information carrier is one way of coping with this risk of sharing information; it can be introduced as an alternative application of technology roadmapping and data gathering, broadening its participatory usage. These applied methods are important, as it appears to be specifically valuable to use case studies combined with theoretical analyses, to understand if roadmapping can serve as a framework for these broader purposes, and thus create value as a tool for handling and sharing knowledge.

As such, roadmaps are not silver bullets; they are rather what could be referred to as boundary objects that set the framework for what is in focus. They may be perceived as an on-going process over a certain period of time. This research therefore opens a new door and welcomes the knowledge management discipline to deal with more epistemological questions of how to handle various stakeholder perspectives and types of knowledge.

6.5. Overall conclusions and reflections

Evolutionary economics embraces a longer time perspective than neoclassical economics' much shorter time perspective, and it is the claim of this thesis that, for future research, foresight methods would benefit theoretically from being grounded in the theoretical foundation that evolutionary economic theory provides. This conclusion is arrived at after reflecting upon this research, and it relates in particular to the characteristic that the roadmap framework is unique compared to other foresight tools. Its framework essentially introduces foresight tools for identifying trends and drivers, but these are then aligned with technological development along a long-term timeline, which opens up for the identification of innovation gaps between today and the desired future (the vision). It therefore essentially captures the important point taken from evolutionary economics that time matters to knowledge.

Chapters two and three complement each other in first giving a narrative perspective on the role of the ETPs in the structural change to a low carbon economy. They also present a study of practice involving a new innovation policy tool and strategy making, as well as strategy implementation, through following the ETPs in wind power and zero emissions from fossil fuel power plants. Since the ETPs have now been in place for some time, it is important to ask about their characteristics and methods supporting such strategic processes. The roadmap processes of these new institutional tools and foresight practices seem to be important influences on policy tendencies.

My research claims that the ETPs are a new innovation policy tool, and that the roadmapping processes are an approach of strategy implementation. EU has a history of failed targets, said one of the leading civil servants I interviewed, and setting targets alone has proven to be a failed strategy. This claim is therefore supported by empirical evidence, along with a theoretical discussion on innovation systems, to show that the industry-led ETP roadmaps clarify future technological trajectories by being implemented into the European Strategic Energy Technology Plan, thus making efforts to align EU policy and industrial innovation efforts. Through these processes, resources are negotiated between the ETPs and the EU Commission. This is a new negotiation process that works from within the system. Thus, the emergence of new types of corporate political strategies is also influenced by earlier studies in corporatism. In Hillmann and Hitt's (1999) terminology, such strategies are called relational approaches, which aim to build trust and legitimacy, as opposed to transnational approaches, where firms formulate political strategies only in response to specific issues. Naturally, firms in highly regulated sectors are likely to be pro-active in pre-political strategy phases that shape public opinion.

The two explorative case studies, the European Technology Platforms in wind and carbon capture and storage, are examples of a new rationale for establishing networks. They are evidence of EU policy makers taking on a more active role than that of administrators, when efforts are made to involve multiple stakeholders from industry in order to create ownership and mobilize private as well as public resources in joint strategic alliances.

Such experimentation with new institutional tools and networks supports social interaction. It enables learning processes and knowledge sharing among these stakeholders at many levels by establishing an infrastructure for the firms to explore innovation opportunities, and also by channeling information from the market to the policy makers. Such new forms of cooperation between the EU Commission and industry are moving beyond lobbyism. It not only becomes important for the processes' legitimacy to justify the choice of who is inside/outside the decision-making system, but also to investigate whether such processes are able to remain open to innovation and when it is time to restructure or simply dissolve the cooperation.

In applying the innovation system approach, the case studies show that even though wind and CCS are both energy technologies, their innovation systems and needs are surely not 'alike'. When comparing the proclaimed barriers and stakeholder interests in the two cases reveal technological characteristics, as well as the different social selection processes forming the platforms.

The firm-level research explored how to design and implement a roadmapping process in a company by aligning marketing and researcher in exploration of the commercial potential of a new drug delivery platform solution. This might be seen as more of a consultancy task than an academic exercise, but it offered the opportunity to supervise a master thesis student and thereby provide some form of spin off from my roadmapping research and knowledge to Novozymes in exchange for insight into an often confidential process inside the company. But in spite of the risk of simply delivering a consultancy job, the article aims to compensate for this by developing the complementary asset identification method that serves as the bridge between explorative roadmapping and the dynamics capabilities theory. Chapter five answers the contextual research questions related to being illustrative: how the conceptual frameworks of a roadmap integrate with a dynamic capability perspective and can be customized to fit the specific needs of the technology in quest of the transition process. Foresight methods and mindset could be one way to cultivate dynamics capabilities.

6.5.1. Reflections on further research gaps

The point of departure was that a gap existed between theory and method. Reflecting on the research of this thesis, which consists mainly of an introduction and four articles, it seems that the problem might have a broader perspective than that a gap exists in foresight literature between theory and practice.

6.5.1.2. Time, knowledge and evolutionary dynamics

When reflecting upon the study as a whole, on what learning I see for the future, I may be turning things upside down: Foresight policy rationales have evidently been piggybacking on innovation policy rationales, and innovation policy has adopted the idea of innovation systems.

As discussed in chapter two, the idea of national innovation systems evidently emerged around the departure in the beginning of the 1980s from user-producer and system thinking in relation to a critique of the linear innovation model, which overlooked the feedback mechanism from the market and production to the R&D system (Freeman, 1979; Lundvall, 1988: 2007; Freeman and Soete, 2009). Therefore, when reflecting upon this literature and this thesis study, it seems that rather than the research gap consisting of gaps in foresight literature between theory and practice, it is the broader developments in innovation system approaches focusing on regional innovation systems, technological systems of innovation, and national systems of innovation that have left policy with a huge gap due to the necessity to cut across many systems of innovations. This has to be the case when the problem is in fact that change processes that relate to low carbon energy systems must first of all build on a low carbon economy; and naturally, the process must move beyond focusing on technology developments alone. It needs co-evolution, e.g., of new forms of collaboration and new forms of investment.

Currently, as the ETP case studies illuminate, the EU policy makers seem to bridge this gap with applied foresight activities, as in the case of the ETPs. Arriving at this discovery calls for even more research and theoretical support in understanding industrial dynamics, the importance of creating space for creativity and experiments, and thus a better theoretical knowledge foundation for applied foresight activities.

Moreover, we need what Brian Loasby, one of the grand evolutionary economists, says in his article, "Time, knowledge and evolutionary dynamics: why connections matter" (2001), an article that I must admit has become quite dear to me, making more and more sense. Loasby says "…*that we must develop theories that are embedded in time – and therefore in uncertainty – and take seriously the selective developments of connections over time as a result of fallible human action"* (p. 402).

As presented in the introduction to this thesis (section 1.1.1. The evolution of foresight rationales), literature presents policy foresight rationales for bringing stakeholders together, building new networks, and thus improving policy-making and strategy formulation in areas where science and innovation play a significant role.

For the sake of both theoretical and practical knowledge, we need methods to understand the impact of bridging theses gaps with foresight activities. We need to measure or evaluate the effect so as to learn from these selective developments in connections over time, and to make them falsifiable. This claim is highly related to the point referred to in chapter two (section 2.3. methodology) of this thesis, that when focusing on a proposed problem of a technology or barrier to bringing a technology to market, it is first relevant to ask whom does it concern, and secondly to ask who is proposing the relevance (Jørgensen et al., 2009). However, after reflecting upon this, I would advocate taking the analysis a bit further on the practical level and analyzing in what way the connectivity has been changing, and what is to be learned from this selective mechanism of building new networks around certain problems.

6.5.1.3. Evolutionary research tracks and entrepreneurial skills

At the meta-level considerations, the study opens a theoretical discussion illuminating the roots of evolutionary economic thought and the idea of entrepreneurial skills that lies in the concept of dynamic capabilities.

As discussed, the dynamic capabilities approach explores the resources needed to profit from innovations, with a focus on not merely gaining from a single invention, but rather sustaining and developing competitive advantages over time. The idea has roots in evolutionary economics and relates in particular to the Schumpeterian idea of creative destruction. It also relies on the notion that new knowledge can create new opportunities, and on Israel Kirzner's related idea about the entrepreneurial skills required to sense new opportunities by taking advantage of existing information (Teece, 2007). These theories describe two forces that are important to the dynamic capabilities approach, namely, creative destruction and the restoration of equilibrium (ibid.). The dynamic capabilities framework highlights that both the companies' resources (capabilities, assets, opportunities) and the ways in which a company accumulates and develops its resources are important for competitive advantage (Teece et al., 1997). To put it simply, the dynamic capability approach takes a broader view of the profiting from technological innovation perspective (Teece, 1986) in order to understand the capabilities a company would require in the future, and translates this knowledge into processes designed to achieve competitive advantage over time. The framework is a strong break from Porter's five forces, in which strategy formulation is focused on coping with competition, as the dynamic capabilities framework focuses on shaping competition itself. Its strategy formulation involves: "*...selecting and developing technologies and business models that build competitive advantage through assembling and orchestrating difficult-to-replicate assets, thereby shaping competition itself"* (Teece, 2007, p. 1325).

Firms and institutions work *from within* the political systems in creating their own future by constantly challenging their path, using an analogy to Schumpeter's creative destruction. The conclusion is therefore much based on the conclusion in chapter three – that specific sectors grow, because they are developed; and they develop, because they are always changing. Therefore, they grow due to the growth of knowledge (Metcalfe, 2011). In evolutionary economics, the foundation is that profitable techniques tend to replace less productive ones through two mechanisms: "*Firms using more profitable technologies grow. And more profitable technologies tend to be imitated and adopted by firms who had been using less profitable ones*" (Nelson, 1995, p.71). It therefore also seems reasonable to deduce from this that the idea of structural change is related to the idea of differential growth. It therefore seems relevant to include both systemic properties and evolutionary properties: If you change the rules of the game that define the order, then naturally you also change the order on which the rules are based, thus causing a new instituted frame for systems to evolve. This is co-development. Moreover, innovation system perspective tells us that firms do not innovate in isolation. In a highly specialized knowledge society, new skills lie in keeping track of the average heading and general speed of the neighboring competitors, firms or research institutes. In many ways, the key players and followers in the ETPs are comparable to the notion of fitness. The ETPs are examples of the restless search to solve problems of scarcity, but this is also what constitutes innovation, and within lies a refinement of the understanding of differential growth. The research study initiates a quest for more research in this direction, moving from entrepreneurship at the individual level to also include studies at the collective level: to reveal how connectivity evolves and changes over time.

The impact of this study is therefore:

- Taking on a long-term perspective opens up for many uncertainties.
- However, uncertainty is also the precondition for creating space for creativity and experiments.

- Innovation is systemic, and thus focusing on single technologies does not give a full perspective, since new technologies are analogue to any discipline jumper. As we say in network terms; what is in the periphery in one network, may be in the core in another.
- The same thing goes for industrial dynamics; and we should not exclude the influence of the incumbent firms on exploring technological trajectories.
- Studying the selective developments in connectivity over time may provide us with an understanding of fallible human action (Loasby, 2001). The method of social network analysis developed in chapter 3 provides a huge potential for further research paths.

An enticing analogy between the idea of fitness and behavior of organizations and innovation efforts using social network analysis is the instinctive flocking of birds when migrating. This is the long stretch, which is based on skills, instinct and vision. By flocking, and especially when migrating, geese align in V formations as to benefit from the evolutionary features this formation given by increasing the average distance an individual can cross: *"…a flock of geese flies 70 percent further then a lone goose. Riding in the wake also helps birds that are less strong and less competent fliers remain with the flock…. Birds flocking in a cloudless, blue, autumn sky may seem like magic, but it's really a combination of vision, instinct, and skill"* (Chandler, C, 2006).

In networks, different power positions exist, and just like the aligned flock of birds flying in the V formation when migrating, these are based on skills, being in the lead position in the V formation also is the one that has to work the hardest. Riding in the wake may not seem like an entrepreneurial position, but it provides knowledge spillovers for being in an entrepreneurial position in a later stage or in another network. I draw here especially on the study of the ZEP platform network over time in the case of the CCS technology, which mainly consists of large, well-established oil and gas companies; later, it will include smaller companies with expertise in emerging technologies such as solar power and hydrogen and fuel cells in the periphery, as the technologies are related.

These meta-level considerations therefore opens up to future research to discover more about industrial dynamics and the impact of policy – e.g. measuring the impact of policy interventions and regulatory initiatives, such as the impact of standards on systems of innovation using social network analysis.

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7. Chapter seven: Summary and reflections

My research at DTU Management Engineering recapitulated in this thesis has focused on change processes that mobilize human action and develop knowledge frameworks in order to improve strategic processes, engage stakeholders and create buy-ins – i.e. ownership of visions and strategic directions. Specific studies were made on what could be called the on-boarding program of the industry-led European Technology Platforms in wind energy and carbon capture and storage technologies, leading to enhanced European innovation efforts and competitiveness. So many learning points must be passed on from observing and measuring the ETPs' performance, the growth in network and information flows between technology users, producers and institutions – and most importantly, the fact that strategy is not an outcome but a process. And technological change is not mechanical or prone to technological determinism. Rather, it is in part a negotiation process between social entities.

Understanding roadmapping has been a journey, also a necessarily diverse journey. It has shown that there is no 'one size fits all' in roadmapping. The articles presenting the research carried out at different socio-economic levels; sector and firm level, show that roadmapping is a flexible tool that can be made to fit the needs of a specific process. Its strength lies in the participatory process and in the action-oriented, systematic framework that aligns layers of information while moving from our current position to where we want to go. It is particularly strong in aligning commercial perspectives, market trends and drivers with technological development and innovation. In the cases of the ETPs, roadmapping is a strategy tool for exploring strategy and also implementing the strategy for EU's 20 percent carbon reduction and 20 percent renewable energy plan by 2020, as it serves as a strong communication tool in visualizing technological trajectories. Path creating and path dependency are parts of a negotiation process between many entities, including social actors. EU has a history of failed targets, which proves that setting targets alone is simply not sufficient. The ETPs and the roadmap processes are something new within the policy paradigm for innovation policy encountering the idea of innovation systems that refer to system failures in contrast to market failure.

Chapters two and three comprise mainly policy-oriented research, which focuses on how theoretical ideas are implemented in practice and aims to understand the processes of the industry-driven ETPs in wind and CCS. What are their characteristics? Why do they emerge now? While discovering the co-development between the shift from a science and technology policy to an innovation policy and participatory processes that shape technological trajectories around major problems, the analogy to systemic innovation is used and explored by investigating how the networks of the ETPs in wind and CCS evolve.

Chapters four and five were more conceptual and relate to processes at the firm level, focusing on development of new conceptual tools for communicating the value of technology between collaborative groups. Chapter four includes a published European Foresight Platform brief, a practical workshop guide for combining future scenarios with the action-oriented roadmapping process in order to explore strategy and innovation. Chapter five then produced a conceptual framework for roadmapping and dynamic capabilities, applied as a corporate foresight framework in Novozymes to create the development path for delivering a new drug. This work resulted from the opportunity to supervise a master thesis in collaboration with Novozymes Bio Business between September 2010 and April 2011. The case involved a new technology within a new business area in biopharmaceuticals for Novozymes. As a result of aligning this new business opportunity with future trends and technologies, the analysis pointed to a drug delivery partnership platform solution based on applied roadmapping combined with dynamic capability thinking. The scenario method allowed for a discussion focusing on possible future paths to pursue. Ten months later, the roadmap and the aligning processes had great impact on Novozymes' path creation, moving it into new markets for biopharmaceutical drug deliveries. Not only did the approach pattern the technology, but the roadmap also led the Novozymes portfolio board to grant the necessary resources, and in January 2012, the Albufuse® Flex received the Drug Delivery Partnership award for the most promising technology of the year at a highly respected conference in Las Vegas. The Novozymes case therefore also serves as strong evidence of the powerful effect of communicating the value of a technology and including such participatory processes in the early path creation.

Such a case study serves to make us reflect on the possible effects of the European roadmaps 2020 in wind power and carbon capture and storage. Such roadmaps are strong tools for communicating the value of new technologies. As new policy tools, the ETPs and the participatory roadmapping processes are creating collective formations to shape technological developments.

Dansk Resumé (Danish popular summary)

I dag ved vi meget lidt om de forandringsprocesser, der er med til at udvælge nogle teknologier frem for andre som værende de kommende vækstteknologier. Det er det overordnede område, som denne afhandling søger at belyse i sammenspillet mellem teknologisk fremsyn og innovation. Afhandlingen belyser mere specifikt de europæiske teknologiplatforme, som med deres industridrevne roadmap-processer er *nye i det politiske landskab*. Et teknologisk roadmap er et fremsynsredskab, der kan anvendes i aktør-netværkssammenhænge til at anlægge et langsigtet markedsperspektiv på teknologiudvikling. En fremsynsproces kan åbne op for mange usikkerhedsparametre, men én af pointerne er netop, at usikkerhed er en væsentlig forudsætning for forandring.

De europæiske teknologiplatforme udgør i dag en central del af EU-Kommissionens instrumenter til at nå de innovationspolitiske mål: at skabe en bedre europæisk innovationsindsats og konkurrenceevne. Platformenes politiske formål understøttes af et innovationssystemperspektiv i form af at bringe centrale innovationsaktører sammen. Afhandlingen vægter herigennem at se innovation som en interaktiv proces i opbygning af kompetencer mellem teknologibrugere, producenter, forskningsinstitutioner og politikkere. Forfatteren analyserer to industri-drevne europæiske teknologiplatforme: én i vindenergi og én i CO_2-indfangning og lagring fra fossile kraftværker. Begge teknologier er udpeget som værende betydningsfulde for den europæiske konkurrenceevne. Samtidig er de centrale midler til at nå EU's energi-og klimapolitiske mål.

Afhandlingens undersøgelser kombinerer en narrativ tilgang i form af interviews, der afdækker innovations- og teknologiske barrierer og en socialnetværksanalyse af interessenternes rolle i de to platforme over en 5-årig periode, gennem hvilke en fælles vision og en strategisk forskningsagenda for 2020 blev skabt. Herved er *nye metoder* til en organisatorisk tilgang til innovationssystemer udviklet, hvor *ny viden* er, hvordan selektionsmekanismer ændrer sig over tid. Den metodemæssige lære åbner op for at se teknologiudvikling som en kollektiv proces, hvor *nye færdigheder* også består i at holde styr på udviklingen af de omkringliggende konkurrenter, virksomheder eller forskningsinstitutter. Afhandlingen bidrager med praksis erfaring med udvikling af roadmap på virksomhedsniveau kombineret med scenarier og dynamiske kompetencer fra strategilitteraturen.

Afhandlingen bidrager således med nyt, idet den sammentænker innovation og fremsynsforskning med afsæt i et evolutionært perspektiv.

The thesis focuses on the coordination of technology-intensive innovation activities at both sector and firm levels, supported by the use of the strategic roadmapping method. Investigations combine qualitative and quantitative research methods; using a narrative approach in the form of interviews to uncover innovation and technology barriers, and a social network analysis of stakeholders' role in relation to two technology platforms during a five-year period when the roadmaps 2020 were developed. In this respect, the thesis emphasizes the view of innovation as an interactive process to develop competences among technology users, producers, research institutions, and politicians. As a result, knowledge on how the platforms evolved, and their dynamics, provide new reflections on the innovation systems approach: that connectivity seems to change along the changes in problem. This is how the players create new knowledge. Thus, the identification of political and technical barriers is important selection mechanisms in how connectivity grows and changes. The thesis, furthermore, includes practical experience and account of roadmap development at the firm level providing reflections on dynamic capabilities.

Understanding roadmapping has been a journey in this research showing that there is no 'one size fits all'. Rather the strength of roadmapping lies in the participatory process and in the action-oriented, systematic framework that aligns layers of information while moving from a current position to a desired future.

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DTU Management Engineering
Department of Management Engineering
Technical University of Denmark

Produktionstorvet
Building 424
DK-2800 Kongens Lyngby
Denmark
Tel. +45 45 25 48 00
Fax +45 45 93 34 35

www.man.dtu.dk